KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

BUREAU OF WATER

SURFACE WATER NUTRIENT REDUCTION PLAN

DECEMBER 29, 2004

ACRONYMS AND ABBREVIATIONS USED IN THIS DOCUMENT

BMP .... Best Management Practice
BNR .... Biological Nutrient Removal
COE .... US Army Corps of Engineers
CWAP .... Clean Water Action Plan
EPA............................ US Environmental Protection Agency
gpd............................. Gallons per Day
HUC .... Hydrologic Unit Code
IPI .... Improvement Potential Index
KDHE......................... Kansas Department of Health and Environment
KSPE .... Kansas Society of Professional Engineers
MDNR .... Missouri Department of Natural Resources
MGD .... Million Gallons per Day
MS4 .... Municipal Separate Storm Sewer System
NPS .... Nonpoint Source
NWR .... National Wildlife Refuge
PS .... Point Source
Res .... Reservoir
RWD .... Rural Water District
SFL .... State Fishing Lake
SOC .... Schedule of Compliance
TMDL .... Total Maximum Daily Load
TN .... Total Nitrogen
TP .... Total Phosphorus
USDA .... US Department of Agriculture
USGS .... US Geological Survey
WA .... Wildlife Area
WQS .... Water Quality Standards
WRAPS .... Watershed Restoration and Protection Strategy
WWTF .... Wastewater Treatment Facility

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I. Executive Summary

High levels of nutrients in surface waters of Kansas stimulate nuisance growths of plants and algae in both streams and reservoirs. Kansas is not alone. To some degree, every state in the nation faces problems associated with nutrient over-enrichment caused primarily by nitrogen and phosphorus in their waters. In many cases, those problems emanate from activities within a state, as well as activities in upstream states.

The highest profile examples of nutrient impairment on the national level are the Gulf of Mexico and the Chesapeake Bay. In the Gulf, hypoxia (the *Dead Zone*) has negatively impacted aquatic life and, subsequently the livelihood of those relying on the natural resources of the Gulf. In the Chesapeake Bay, similar impacts on wildlife and the seafood industry have been felt.

In Kansas, numerous lakes and streams have been identified as impaired by nutrients. Most visible have been those drinking water reservoirs affected by toxic algae blooms as well as taste and odor problems associated with drinking water.

Because of the widespread, interstate scope of the nutrient issue, the US Environmental Protection Agency (EPA) has requested all states develop plans to establish water quality criteria for nutrients in surface waters. The criteria would establish the maximum accepted concentrations of nutrients in surface waters that would allow those waters to support uses such as drinking water supplies, fishing and swimming.

Unfortunately, there is much debate on how to establish the appropriate *criteria* for protecting the uses mentioned above. Unlike most pollutants which currently have criteria established, no single criterion value appears to be appropriate for every water. Numerous site specific factors could lead to individual criteria for every waterbody. Identifying those site specific criteria could take several years to develop. In the meantime, nutrient enrichment would continue to impair water supplies, recreation and aquatic life support.

Actions to control nutrients, however, should not be delayed simply because criteria are not feasible at this time. Control of nutrients must be addressed for Kansas as well as much of the Nation in the near term. This Plan seeks to place the State of Kansas in a leadership position within the Mississippi River Basin by proposing a pragmatic initial step to controlling nutrient releases - specific controls for large sewage treatment plants, along with targeted activities for nonpoint sources of nutrients. By limiting releases of nutrients in the near term Kansas can markedly improve water quality and help extend the life of valuable drinking water and recreation resources, while continuing to explore criteria-based options.

II. Problem Definition

The adverse effect of nutrient enrichment on our waters has been identified as a major environmental issue in Kansas and the nation. *The National Water Quality Inventory: 2000 Report* cites nutrients as one of the leading causes of water quality impairment in waters of the United States, primarily due to *eutrophication*.

Eutrophication is the process by which impoundments age and become more productive – i.e. experience enhanced plant and algal growth. Excess plant and algae growth is primarily caused by the nutrients phosphorous and nitrogen added to a waterbody. Eutrophication accelerates the aging process via increased siltation and loss of dissolved oxygen. The report estimated 20% of the nation's rivers and 50% of the nation's lakes were impaired due to nutrient enrichment (United States Environmental Protection Agency [USEPA], 2002).

Cultural eutrophication refers to the process where human activities accelerate eutrophication by speeding up enrichment. Human activities exacerbate nutrient over-enrichment through two primary means – 1) point sources, i.e. sewage treatment facilities; and 2) nonpoint sources, the nutrient-laden runoff from urban and agricultural areas as well as atmospheric deposition. Estimates indicate point sources account for 5 to 30% of the nutrient load to waterbodies, with nonpoint sources responsible for the remainder.

Nutrients have been implicated as a principal source of hypoxia in the Gulf of Mexico. Hypoxia has led to a so-called "Dead Zone", where depleted oxygen levels have led to the death of bottom dwelling organisms and driven mobile marine life from the area. In 2002, it was estimated the areal extent of the Dead Zone approached the size of the state of Massachusetts (Greenhalgh & Sauer, 2003).

It is believed the size of the Zone is primarily correlated to the amount of total nitrogen (TN) delivered to the Gulf by the Mississippi River drainage basin, which includes Kansas (USGS, 2000). Total phosphorus (TP) plays a lesser defined role. Meeting a reduction goal of 30% of the mass of TN delivered to the Gulf could result in as much as a 50% increase in dissolved oxygen in the Northern Gulf (Brezonik et al., 1999).

Total phosphorous has been implicated as the limiting factor in most lakes/reservoirs within the state. In other words, phosphorus is the primary nutrient requiring control within the boundaries of the state. An increased TP load can cause the production of algae and/or plants which have the potential to adversely affect biological diversity, water quality, and drinking water quality.

In particular, when phosphorus is available in excessive amounts, blue-green algae or cyanobacteria can dominate. Cyanobacteria cause taste and odor problems with drinking water and produce toxins that can affect humans and animals.

KDHE recognizes there could be other factors that affect eutrophication, such as micronutrients, light, temperature, and sediment. Excess nitrogen and phosphorus, however, are the key drivers, and the primary focus of this plan. Significant progress in mitigating the effects of eutrophication can be achieved by reducing these two nutrients.

In order to facilitate nutrient reduction and mitigate eutrophication with its attendant negative impacts, KDHE has developed this Nutrient Reduction Plan. When implemented, the Plan provides a framework for making meaningful reductions in nutrients. While the positive effects of nutrient reduction and control will probably not be noticed immediately, a long term improvement in water quality within Kansas and downstream of Kansas will be achieved.

III. Regulatory Background

A. Federal Actions

- February 14, 1998 – EPA released the *Clean Water Action Plan* (CWAP). The CWAP identified nutrients as a significant source water quality impairment and announced that EPA would develop nutrient criteria by 2000.

- June 25, 1998 – EPA announced its National Nutrient Strategy in the *Federal Register*. The Strategy indicated EPA would develop nutrient criteria by the end of 2000, and States would have to adopt those criteria, or state-derived criteria, by the end of 2003. (Notice of National Strategy for the Development of Regional Nutrient Criteria, 1998).

- January 9, 2001 - In accordance with section 304(a) of the Clean Water Act, EPA announced the publication of seventeen Ecoregional Nutrient Criteria Documents for lakes and reservoirs, and rivers and streams for specific geographic regions (ecoregions) of the United States in the *Federal Register*. Additional documents were to be published at a later date. The goal of these documents was to give States a starting point in developing more refined numeric nutrient criteria. EPA encouraged States to refine the recommendations based on key elements, such as historical information, reference conditions, models, consideration of downstream effects, and expert judgment unique to each state.

  The announcement also introduced the concept of a *nutrient criteria plan*. The plan, to be developed by each state, was to lay out a timeline for adopting nutrient criteria.

  The plan was to be submitted to EPA by the end of 2001, with the expectation the plan would require nutrient criteria be adopted by the end of 2004. (Nutrient Criteria; Notice of Ecoregional Nutrient Criteria, 2001)

- November 14, 2001 - Geoffrey Grubbs, Director of the EPA Office of Science and Technology, issued a memorandum titled *Development and Adoption of Nutrient Criteria into Water Quality Standards* (G. Grubbs, memorandum, November 14, 2001). The purpose of this memorandum was to further explain the concept of *nutrient criteria plans.*

The memorandum discussed the role of the plans, as well as the flexibility, expectations, and timeframes for developing a plan and adopting nutrient criteria into a state's water quality standards. The memorandum also answered questions from States and stakeholders concerning the implementation of nutrient criteria. The memorandum delineated the expectation states would have plans adopted, and be in the implementation process by 2005. If not, EPA would move to adopt criteria for states.

- October 2002 - EPA indicated that it would no longer require states to have nutrient criteria in place by 2004, but still expected nutrient criteria development plans to be submitted as soon as possible.

  This plan has been developed based on that request and the recognized need to address nutrient enrichment.

B. State Actions

- May 1, 1987 – Kansas adopted narrative nutrient criteria into the Kansas Surface Water Quality Standards.

- June 30, 1999 – Kansas submitted the first Total Maximum Daily Load (TMDL) documents based on the state narrative nutrient criteria to EPA.

- February 11, 2002 – KDHE staff initiated a meeting with EPA staff to discuss a draft nutrient criteria plan. The essence of the plan was to develop site specific nutrient criteria for large public water supply reservoirs in Kansas, while implementing best management practices to control nutrient addition to streams.

  KDHE staff asserted the EPA-developed ecoregional criteria were believed to be unachievable, and would likely never be met in Kansas reservoirs or streams, even if elaborate measures were taken to control sewage treatment plants and nonpoint sources. KDHE received no encouragement from EPA to submit the plan.

- November 11, 2002 – KDHE published a White Paper on nutrient criteria as a part of the triennial review of the Kansas Water Quality Standards (WQS).

  Nutrient criteria had been identified as one of six key WQS issues by a focus group consisting of environmental groups, the regulated wastewater community, industry, and scientific experts. The focus group approved the White Paper which was published in advance of 17 public meetings held to accept public input on the WQS and placed on the KDHE World Wide Web site.

- November 14, 2002 – KDHE placed a notice in the *Kansas Register* informing the public of seven statewide meetings regarding KDHE's intent to receive comments on the WQS triennial review. The notice provided information regarding the above mentioned White Paper.

- December 2, 2002 – A statewide press release was issued informing the press of seven statewide meetings regarding KDHE's intent to receive comments on the WQS triennial review. The notice provided information regarding the above mentioned White Paper.

- December 17, 2002 to January 22, 2003 – KDHE staff held seven public meetings throughout the state to solicit comments on a nutrient criteria plan, as well as other WQS issues as a part of the triennial WQS review process. Meeting locations included Hays, Colby, Manhattan, Wichita, Overland Park, Garden City, and Independence.

- January 6, 2003 to March 5, 2003 – KDHE staff attended ten Basin Advisory Committee meetings and made presentations on the WQS triennial review process. Comments on a nutrient criteria plan, as well as other WQS issues related to the triennial WQS review process were solicited from the Committees and the public in attendance.

- January 23, 2004 – KDHE staff met with the Kansas Society of Professional Engineers (KSPE) Environmental Resources Committee to present a conceptual proposal for nutrient control that was the genesis of this plan. Most discussion dealt with impacts on sewage treatment plant design.

- February 6, 2004 – KDHE staff discussed a conceptual proposal for nutrient control at a League of Kansas Municipalities Leadership Academy session dealing with environmental issues. Municipalities will likely be affected by any plan to control the release of nutrients.

- April 12 and 14, 2004 – KDHE staff discussed a conceptual proposal for nutrient control at the Kansas Water Environment Association Annual Conference. This was a varied group of municipal, industrial, private sector, and government officials involved in water quality issues.

- April 23, 2004 – KDHE staff met with the KSPE Environmental Resources Committee to present a refined proposal for nutrient control that is the genesis of this plan.

- November 1, 2004 – KDHE staff met with representatives of several agricultural groups to discuss the conceptual nutrient reduction plan.

- November 4, 2004 – KDHE staff discussed the conceptual proposal for nutrient control at a *Watershed Management Seminar* sponsored by KDHE and Kansas State University.

- November 15, 2004 – KDHE staff met with members of the Kansas Biological Survey to discuss the conceptual nutrient reduction plan.

- December 2, 2004 – KDHE staff met with the Governor's Subcabinet on Natural Resources to discuss the conceptual nutrient reduction plan.

  The Subcabinet consists of the Agency heads for KDHE, the Kansas Department of Wildlife and Parks, the Kansas Department of Agriculture, the Kansas Water Office, the Kansas Corporation Commission, the Kansas Department of Animal Health, and the State Conservation Commission.

There were few suggestions provided at the public meetings regarding nutrients. The general tone of comments received was that nutrient criteria appeared to be unworkable without considerably more data collection and analysis. Therefore, KDHE began developing a strategy to make meaningful nutrient reductions without attempting to force unsupportable numeric criteria.

This Plan documents the reduction strategy, and is intended to provide EPA and the public an understanding of the processes and methods KDHE believes can be effectively used to reduce nutrients in Kansas and downstream waters.

Through the Plan, a series of actions are outlined that would ultimately result in improved local water quality as well as meet Kansas' responsibility to protect downstream water quality.

IV. Nutrient Criteria Approach

A. Criteria Development

Based on its 1998 Nutrient Strategy, EPA developed an ambitious plan to initiate the adoption of nutrient criteria within a very short timeframe. The urgency of the plan revolved around the fact that nutrients were, and still are, one of the major contributing factors to degraded water quality in the United States.

Ultimately, in the urgency to develop nutrient criteria, a simplistic method was utilized that relied on a statistical exercise using all available existing water quality from 14 "ecoregions". *Ecoregions* are defined as areas of relative homogeneity in ecological systems and their components.

Possible concerns with the approach have been raised by the U.S. Geological Survey (USGS) and several States. The USGS predicted that estimated *background* concentrations for total phosphorus exceed EPA criteria in 52% of stream reaches nationwide (Smith et al., 2003).

In other words, over half the streams nationwide might not be able to meet the EPA-derived criteria for phosphorus due to *natural background conditions*. The USGS report concluded the reason for the high percentage of criteria exceedances was due to wide variability in nutrient concentration occurring in very short distances within the same ecoregions.

Due to uncertainties in deriving and implementing numeric nutrient criteria, States have made only small strides in nutrient control. The inability of states to establish and implement numeric nutrient criteria was borne out in the results of a survey conducted by America's Clean Water Foundation (Poole, 2004). The survey results from 45 states indicate a general uneasiness with numeric nutrient criteria, particularly in flowing waters. There simply are not adequate links between cause and effect – the concentration of nutrients in a waterbody that lead to effects that impair the water body's use.

Many states also expressed the concern that moving forward with poorly developed nutrient criteria would cause loss of credibility for the state agencies and lead to prolonged legal and political conflicts that would further delay effecting any appreciable reduction in waterborne nutrients.

B. Criteria Impacts

The initial impact of nutrient criteria would be felt almost exclusively by sewage treatment plants. Federal regulation [40 CFR §122.44(d)] mandates sewage treatment plant permits contain limitations for pollutants that "*contribute to an excursion above any State water quality standard*". Thus, if a state adopts standards for nutrients, sewage treatment plants would be required to treat nutrients to the degree that their discharge to surface waters would not cause the in-stream nutrient criteria to be exceeded. While the intent of the regulation is sound, its applicability to the current state of the science for nutrients is debatable.

First, as stated previously, sewage treatment plants are responsible for 5–30% of the nutrient contribution in many states, with nonpoint sources responsible for the remainder. The vast majority of the nonpoint sources are unregulated under the Clean Water Act. Therefore, while there are few mandatory actions required for the majority of waterborne nutrients, there are mandatory requirements for the minority sources. This raises the argument of fairness. Should a minority of the problem bear the entire cost of mitigation?

Second, for most pollutant parameters found in sewage treatment plant discharge, it is assumed there is some assimilative or dilution capacity in the water receiving treated sewage. However, most streams and lakes in Kansas currently fail to meet the published EPA nutrient criteria. As such, there is no assimilative dilution capacity for sewage treatment plant discharges. Thus, sewage treatment plants would be given permit limitations matching the nutrient criteria at the end-of-pipe.

Unfortunately, meeting the currently published nutrient criteria at the end-of-pipe is beyond the capability of today's tertiary treatment technologies. For Kansas streams, EPA's ecoregional criteria range from 0.56 to 2.18 mg/L for TN and from 0.020 to 0.067 mg/L for TP. The best performance expected for municipal wastewater treatment facilities utilizing biological, physical, and chemical treatment methods is around 3.0 mg/L TN and 0.3 mg/L TP (Oldham & Rabinowitz, 2002). In other words, current treatment technology cannot meet the ecoregional criteria – in some cases by an order of magnitude.

In addition to the issues with treatment efficacy for nutrient removal, the treatment technology is typically beyond the financial and technical capabilities of the many small towns that comprise Kansas. Based on cost data developed by Foess, the cost per household for a biological nutrient removal facility ranges from $300/month for a population of 100 to over $80/month for a population of 1000 (Foess, Steinbrecher, Williams, & Garrett, 1998). These monthly rates are representative of a facility that can produce an effluent with 6 mg/L of TN and 2 mg/L of TP, and are approximately three to ten times higher than the typical Kansas sewer rate.

Thus, by adopting nutrient criteria, in particular the EPA published criteria, rate payers would be asked to fund expensive treatment upgrades that would address only a fraction of the overall waterborne nutrient load and still not comply with permitted limits. (Calculations for treatment costs are included in Appendix A)

If sewage treatment plants could not meet end-of-pipe nutrient limitations, the surface waters in question would typically remain impaired based on EPA's criteria and require development of a total maximum daily load (TMDL). Assuming all sewage treatment plants maximized removal of nutrients, the only sources left would be nonpoint. Since nonpoint sources are largely unregulated, the TMDL could do little more than suggest voluntary nonpoint source controls.

In summary, the current approach to nutrient reduction and control has consisted of a push to develop nutrient *criteria*. Like few other regulated pollutants, nutrients are overwhelmingly derived from nonpoint sources. However, since nonpoint sources are largely unregulated, point source sewage facilities would be held solely accountable for reduction of nutrients in the regulatory arena if criteria were adopted. It is difficult to justify this disproportionate impact from nutrient criteria derived using questionable methodology. The criteria methodology utilizes a statistical approach that attempts to predict a relatively unimpacted condition rather than relying on a more traditional approach that seeks to establish criteria based on protecting against health, aquatic life, or recreational impairments.

While disproportionate impact and criteria development methodology weigh against adoption of nutrient criteria, there is ample evidence to support the need for nutrient reduction and control in Kansas: 1) Kansas currently has developed nearly 200 nutrient-related total maximum daily loads for streams and lakes; 2) Blue-green algae have caused taste and odor problems for numerous reservoir water supplies in Kansas; and 3) Blue-green algae blooms at Marion and Cheney Reservoirs have caused both drinking water and recreation problems.

To address the growing problem of nutrient-induced water quality impairments, an alternate approach has been developed to reduce and control nutrients that would produce tangible water quality improvements. The key elements of this approach follow.

V. Nutrient Reduction, an Alternate Approach

The impacts of nutrients originating in Kansas have been well documented – Gulf of Mexico hypoxia, excessive productivity in Kansas and downstream reservoirs, and taste and odor problems in drinking water originating from reservoirs. Reduction and control of nutrients is needed to begin mitigating those impacts.

The concept of this alternate approach is easily understood – develop an inventory of nutrients entering the waters of the state and ultimately leaving the state, then establish a fixed reduction target. The fixed target, while not criteria, would provide an easily understood, measurable objective. Furthermore, establishing a goal of nutrient reduction precludes the likelihood of a protracted debate surrounding the establishment of nutrient criteria, while the need for reducing nutrients in Kansas waters is imminent. To reach the target, KDHE anticipates NPDES permitting in conjunction with best available technology for municipal wastewater treatment facilities, nutrient trading between point and nonpoint sources, and focusing federal grant monies in addressing priority nonpoint sources would produce the desired results.

The concept of nutrient reduction in lieu of criteria has been utilized successfully in the United States and abroad. Internationally, the European Union has established reduction goals for nitrate coupled with technology-based limits for wastewater treatment facilities (Europa, 1991). A similar approach utilizing nutrient reduction goals has been developed for the Gulf of Mexico (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2001). Additionally, other states, including Connecticut and North Carolina, have addressed nutrient control by establishing reduction targets (USEPA, 2003).

A. Nutrient Export Budget

To begin the process of establishing a target value, a baseline nutrient export budget needed to be established. In addition, estimates of the point source (wastewater treatment facilities), and nonpoint source (runoff and atmospheric deposition) contributions of nutrients was needed to assess the impact of various control strategies.

Utilizing existing data, KDHE developed a nutrient export budget. Data utilized include:

1. Ambient stream monitoring for concentrations of TN and TP from all routine sampling sites where waters exit the state (see Appendix B).

2. Discharge monitoring report data from Kansas wastewater treatment facilities.

3. KDHE's study of lagoon treatment efficiency (Tate, Mueldener, Geisler, & Dillingham, 2002).

Based on an analysis of the data, Table 1 displays the mass of TP and TN from point and nonpoint sources predicted to leave the state on an annual basis.

Table 1 – Nutrients Exiting Kansas

	Tons Exiting Kansas Annually			
Parameter	Total	Point Source	Nonpoint Source	PS % of Total
TN	51,000	9,215	41,785	18%
TP	7,700	1,925	5,775	25%

While the proportion of point source contributions is small compared to nonpoint source, the amount is significant nonetheless. Additionally, nutrient species in wastewater effluent tend to be soluble, thus readily bioavailable. A further analysis indicates 85% of the point source flow can be assigned to large dischargers – those with a design flow of one million gallons per day (1 MGD) or greater. Thus, a relatively small number of wastewater treatment facilities are responsible for the vast majority of the point source contribution.

B. Gulf of Mexico Hypoxia & Total Nitrogen

As stated previously, total nitrogen has been implicated as the primary cause of hypoxia in the Gulf of Mexico. Drainage from Kansas eventually finds its way to the Gulf via the Missouri and Arkansas River drainage basins; therefore, some fraction of TN leaving Kansas eventually winds up in the Gulf.

Studies on the Gulf hypoxia issue predict anywhere from 3% to 13% of the TN reaching the Gulf is from wastewater treatment facilities in the Mississippi River drainage (Goolsby et al., 1999).

Why do Kansas sources appear to contribute a larger percentage of nitrogen to the Gulf than the Mississippi-Missouri basin average for point sources? A study by Alexander and others found that the proximity of nitrogen sources to large streams was a major factor in delivery of nitrogen to the Gulf (Alexander, Smith, & Schwarz, 2000). In other words, a source close to a large stream is more likely to export nitrogen to the Gulf than a similar source located near a small stream.

Figure 1 indicates the predicted percentage of TN that would be exported to the Gulf from each of the eight-digit hydrologic unit code (HUC8) drainage basins in Kansas as well as the location of large point sources. The drainage basins with the greatest export percentages are located near the largest rivers and streams in the Eastern half of Kansas. The major point sources are predominantly located near the HUC basins with the largest nitrogen export potential. Thus, a large percentage of nitrogen discharged from point sources is likely transported to the Gulf.

Conversely, much of the potential nonpoint source input for nitrogen (runoff from fertilizer and manure) occurs in drainage basins with much less probability for transport to the Gulf. Figure 2 displays the average annual nitrogen fertilizer sales in each Kansas County for the years 2001 and 2002 as reported to the Kansas Department of Agriculture (Kansas Dept. of Agriculture, 2004). The heaviest sale of nitrogen is located in the western half of the state. However, the potential for nitrogen to be exported from the western part of the state to the Gulf is minimal. Unlike some other Farm Belt states where nonpoint sources are major contributors statewide, much of western Kansas contributes little nitrogen to the Gulf.

Large point sources, on the other hand, do contribute a substantial amount of nitrogen. Thus, the PS:NPS ratio for Kansas is higher than in many other Farm Belt states.

Similarly, the US Department of Agriculture has compiled data for manure production across the United States (Kellogg, Lander, Moffitt, & Gollehon, 2000).

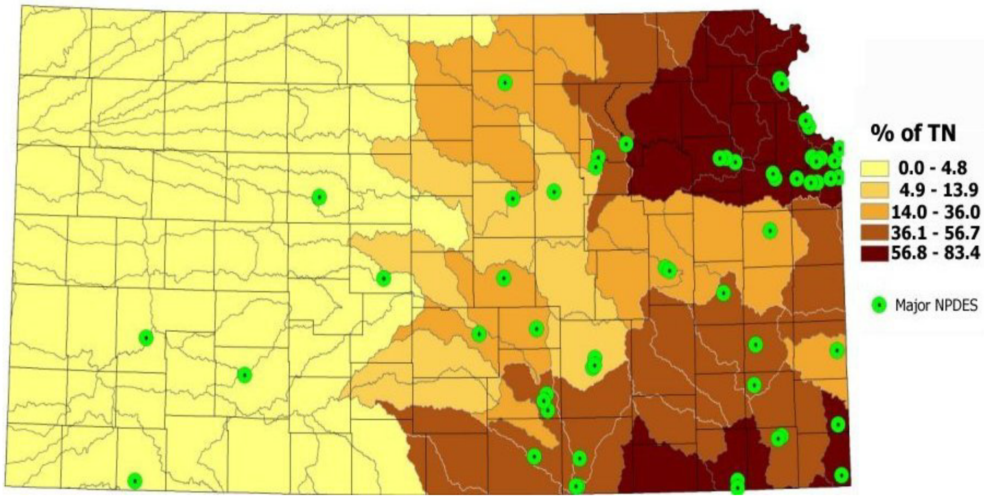

Figure 1 – Percent of Nitrogen Transported to the Gulf of Mexico by Hydrologic Unit Code. Note – The darker the color, the greater percentage of transport. The circles indicate the location of major wastewater dischargers.

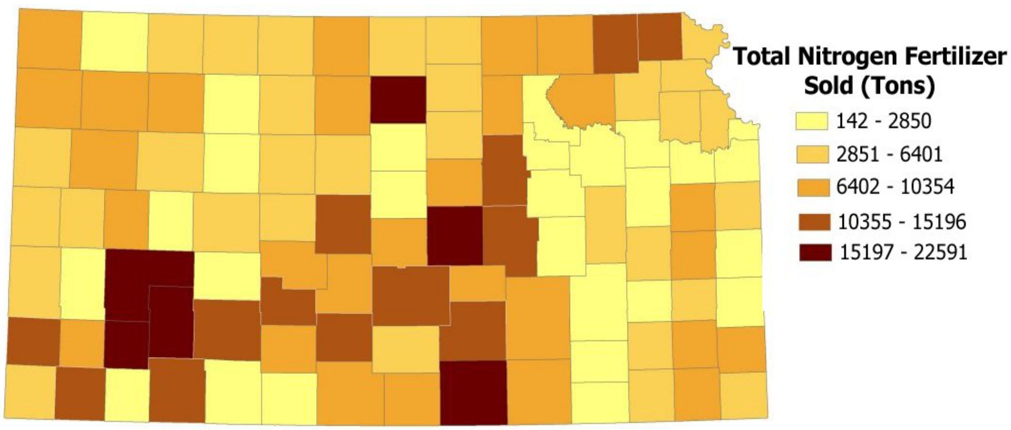

Figure 2 – Average Annual Tons of Nitrogen Fertilizer Sold In Kansas Counties (2001 – 2002). Note – The darker the color, the greater quantity of nitrogen sold.

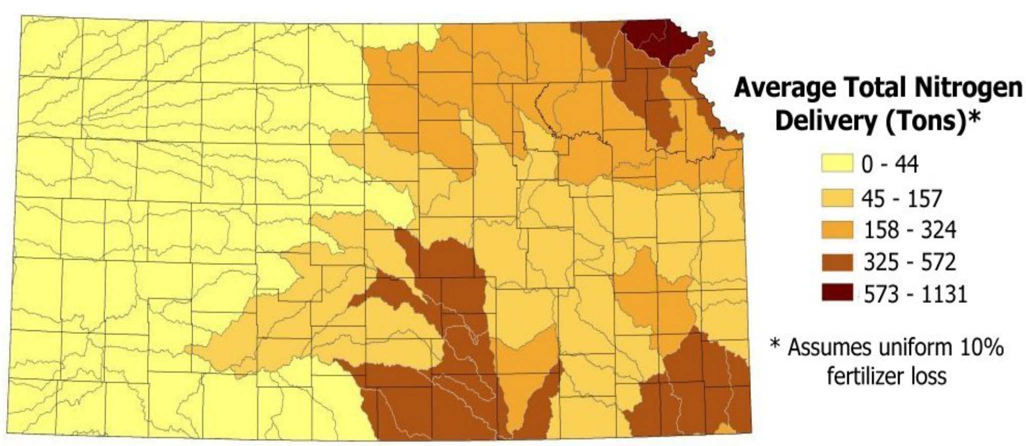

Figure 3 – Average Annual Nitrogen Fertilizer Delivery To The Gulf of Mexico (2001 - 2002). Note – The darker the color, the greater percentage of transport.

The data indicate if: 1) manure is applied to land using best management practices, and 2) **all** available crop and pasture land in Kansas counties is used for application, only one county in Western Kansas would have concerns with management of the quantity of manure produced in that county. The key emphasis is that **all** available crop and pasture land in a county be used.

A much different story arises if the manure produced remains on the original farm site. Under those circumstances, an excess of manure-based nitrogen would exist on some farms in most Kansas counties (See Appendix C for copies of the USDA maps indicating the locations and quantities of excess manure nitrogen). In essence, if manure is managed properly (including exporting from the farm of origin in many cases), land application of manure can be balanced with crop uptake. If it is not managed properly, runoff to surface water will occur.

To indicate which basins would transport the greatest fertilizer-based nitrogen load to the Gulf, the nitrogen sold in each county, was coupled with the percentage of nitrogen delivery in each basin (Figure 3). A simplifying assumption was made that 10% of the fertilizer would runoff. That value is within the range typically anticipated for runoff of 2% to 20% reported by the Fertilizer Institute (Carey et al., 1999). Regardless of the percentage chosen, however, the *relative* ranking of the basin contributions will remain the same. Based on the results presented in Figure 3, the greatest total nitrogen fertilizer transport out of Kansas is most likely to occur in the eastern half of the state, even though more nitrogen fertilizer is sold in the western half. In particular, the extreme northeast corner of the state has the potential for the greatest export of nitrogen to the Gulf of Mexico. The primary reason goes back to Alexander's finding that nitrogen transport increases proportionally with stream size. The larger streams in Kansas are located in the eastern half of the state.

While Figure 1 indicates the most likely areas for point sources of nitrogen transport, Figure 3 represents the most likely areas for nonpoint source fertilizer contribution. Comparing Figure 1 to Figure 3, it is evident there is significant overlap between transport potential for point sources and nonpoint sources in the same basins. Those basins indicate the areas where initial implementation efforts for controlling fertilizer-based nitrogen should be focused. Subsequent efforts should be focused on those areas where point and nonpoint sources do not overlap, but with the highest potential for transport of either point *or* nonpoint source nitrogen.

C. Localized Phosphorus Impairments

As indicated previously, phosphorus is more of a localized issue in lakes and reservoirs. However, phosphorus does play a role, albeit smaller than nitrogen, in the Gulf of Mexico hypoxia issue.

Based on the data generated in Table 1, phosphorus is less plentiful than nitrogen in Kansas river and stream export. Phosphorus however is required in much smaller quantities than nitrogen for algal and plant growth. Typical ratios of TN:TP in surface waters are in the 10 to 20:1 range. In other words, phosphorus is typically more limiting in comparison to nitrogen.

Phosphorus is typically the limiting nutrient in algal growth in Kansas reservoirs. As noted in Table 1, on a percentage basis, point sources play a greater role as the source of exported phosphorus than they do for nitrogen. It is estimated point sources account for 25% of phosphorus leaving the state.

The presumed reason is that the percentage of phosphorus trapped by reservoirs is much greater for nonpoint sources since the majority of the major point source discharges are not ultimately impounded by in-state reservoirs. Reservoirs trap soil by their design, and much of the nonpoint source phosphorus entering reservoirs is attached to soil particles.

The locations of major wastewater treatment facilities in relation to major streams and reservoirs are shown in Figure 4. Note that the majority of the effluent from those facilities is not captured in Kansas reservoirs. The facilities tend to lie on free flowing streams and rivers, thus much of the phosphorus in wastewater effluent is probably transported out of state or assimilated by stream biology rather than entering Kansas reservoirs.

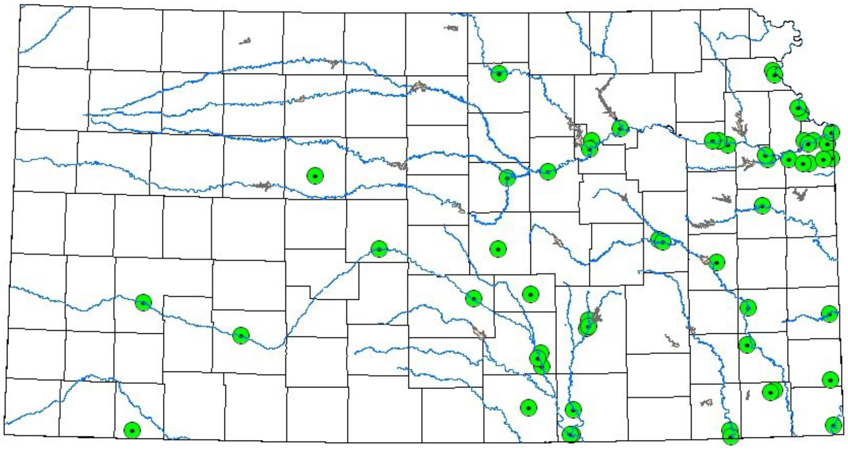

Figure 4 – Location of major wastewater dischargers in relation to major rivers and reservoirs. The circles indicate the location of major wastewater dischargers

The impact of nutrients is not limited to Kansas reservoirs; they also affect downstream reservoirs. Oklahoma has several large reservoirs immediately downstream of Kansas – Copan, Hulah, Kaw, Oolagah, and Grand Reservoirs – which receive a majority of their inflow from drainage in Kansas. Additionally, Truman Reservoir in Missouri receives drainage from the Marais des Cygnes, Little Osage and Marmaton Rivers, which originate in Kansas. All of these reservoirs were designed as sources for water supply (US Army Corps of Engineers [COE], 2004, and MDNR, 2003).

In order to prolong the useful lives of drinking water reservoirs and to mitigate the use of costly treatment techniques, it is imperative eutrophication be slowed. The most effective way to slow eutrophication is to reduce the input of nutrients – primarily phosphorus.

Regardless of the large percentage of nonpoint source phosphorus, there is a significant portion of the phosphorus load contributed by point sources. That load needs to be reduced in order to improve water quality within Kansas and across Kansas borders. Of particular concern are reservoirs used as public water supplies. The impact of eutrophication on public water supplies is manifested by additional expensive treatment for taste and odor as well as algal toxins. Currently, 54 reservoirs in Kansas serve as sources of water supply to nearly 50% of public water supply customers in Kansas either directly or indirectly.

Figure 5 represents at-risk reservoirs based on their susceptibility to nonpoint sources of phosphorus. The graphic depicts the location of major reservoirs in Kansas and their relationships to areas of phosphorus fertilizer sales. Those reservoirs lying within or downstream of counties with the highest phosphorus fertilizer sales would be high priority candidates for attenuation of fertilizer-based phosphorus.

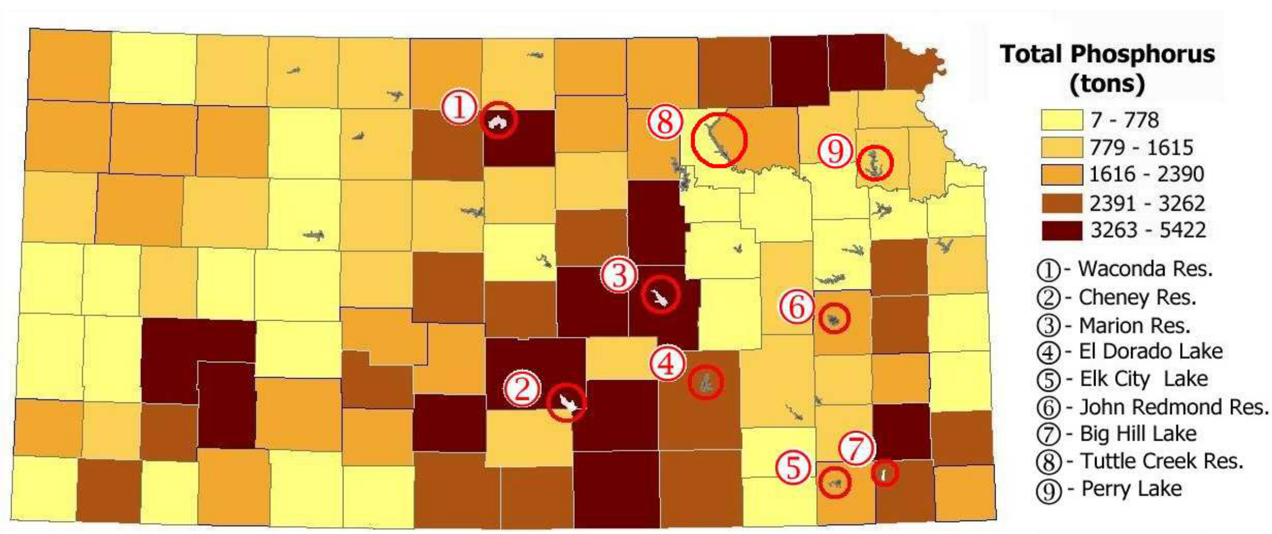

Figure 5 – Location of major reservoirs in relation to county phosphorus fertilizer sales. The darker colors indicate higher sales

Like the findings regarding manure-based nitrogen, Kellogg found that excess on-farm manure-based phosphorus was widespread in Kansas.

Again, while there is less potential for phosphorus transport to reservoirs out of the state from western Kansas, there is significant potential for phosphorus runoff to in-state reservoirs. (See Appendix C for copies of the USDA maps indicating the locations and quantities of excess manure phosphorus). This is particularly true if manure is not applied agronomically, which in many cases requires exporting manure off of the farm of origin.

D. Reduction Targets

- Nitrogen

Reduction targets for nitrogen in the Gulf of Mexico have been established by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force at 30% from the Mississippi River drainage basin (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2001). It has been estimated a 30% reduction would increase bottom level dissolved oxygen in the Gulf by as much as 50% (Brezonik et al., 1999). Simplistically, if each state in the Mississippi River drainage reduced their contribution by 30%, the overall goal of a 30% reduction would be met. Notably, the 30% reduction goal has been recognized by the Governors of Minnesota and Wisconsin (Minnesota, 2004). The two Governors are encouraging other states in the Mississippi River watershed to help address the nutrient issue.

An overall 30% reduction in nitrogen appears to be attainable for Kansas by utilizing a combination of point and nonpoint source controls.

- Phosphorus

Reduction targets for phosphorus are not as well defined at this point. However, it has been estimated by Brezonik that a 30% reduction in phosphorus will bring about 10% increase in the number of flowing waters in the Mississippi River basin that would meet a proposed phosphorus criteria for flowing water of 0.1 mg/L.

In addition, an overall 30% reduction would slow eutrophication in Kansas and downstream reservoirs and aid in maintaining a N:P balance that would dissuade to cyanobacteria.

An overall 30% reduction in TP appears to be attainable for Kansas by utilizing a combination of point and nonpoint source controls. However, as indicated by lake TMDLs, greater reductions may be needed to restore and protect reservoirs for drinking water, recreation and aquatic life support.

E. Reduction Plan

In order to achieve the 30% reduction goals for nitrogen and phosphorus, a coordinated effort of both point and nonpoint source reductions will be required.

- Point Source Reductions

Point sources provide the easiest opportunity to reduce nutrients, since the wastewater containing the nutrients is brought to a single location where it can be managed. Proven technology also exists for removal of nutrients from wastewater that is simply an extension of the biological treatment processes practiced at most larger wastewater treatment facilities (WWTFs) in Kansas. Because larger WWTFs already have the majority of the infrastructure and expertise in place to perform enhanced nutrient removal, the focus for additional nutrient removal will be on those larger facilities. For the purposes of this plan, "large" WWTFs are defined as those with a design capacity equal to or greater than one million gallons per day (1 MGD). One million gallons per day of wastewater equates to an approximate population served of 10,000 persons.

The wastewater discharged from 1 MGD and larger plants accounts for approximately 85% of the wastewater discharged in Kansas. Therefore, application of nutrient removal at these larger, more sophisticated facilities would address the vast majority of wastewater flows in Kansas. The remainder of the wastewater discharged in Kansas originates at small "mechanical" plants and simple wastewater treatment lagoons. Lagoon treatment is the only feasible treatment technology for the many small towns in Kansas - the technology is not complicated, nor is it expensive to operate.

Lagoon technology has also been proven to be an effective means of removing nutrients from wastewater. In Kansas, TN reduction from well designed lagoons is in the range of 67% while TP reduction is approximately 55% (Tate et al., 2002).

In order to enhance nutrient removal at larger WWTFs, biological nutrient removal (BNR) has been used with good success in the United States. BNR is a modification of traditional biological treatment processes utilized by the majority of large WWTFs in Kansas. Studies have indicated that BNR processes in municipal wastewater treatment can typically achieve TN and TP reduction of around 65%. The US Army Corp of Engineers estimates BNR will typically reduce TN to approximately 6 mg/L, and phosphorus to 1.5 mg/L (COE, 2001). Information provided by Bond and others indicates TN concentrations of 8 to 10 mg/L are more realistic (D.M. Bond, personal communication, December 1, 2004). In addition, some industries can utilize BNR to reduce nutrient discharges. However, due to the varying nature of industrial wastewaters, nutrient reduction levels would have to be ascertained on a case-by-case basis.

The addition of chemicals and filtration to the end of the BNR process can be used to achieve higher nutrient removal efficiencies – particularly for phosphorus. This plan does not propose chemical addition and filtration for several reasons: 1) chemical addition adds additional metal salt pollutants to the discharged wastewater, 2) chemical handling presents a number of safety issues to WWTF operators, and 3) chemical addition and filtration is an expensive addition in relation to the benefits provided. Studies have indicated chemical addition and filtration for phosphorus reduction can increase initial capital costs by over 300% and double annual operation and maintenance costs compared to BNR alone (Faeth, 2000).

Based on expected removal efficiencies for BNR, it is feasible for the large WWTFs in Kansas to meet effluent limitations of 8 mg/L for TN (~67% reduction) and 1.5 mg/L for TP (~65% reduction) on an ANNUAL AVERAGE basis.

The impact of these reductions would be environmentally significant. Based on the data from Table 1 and the following calculations, the overall export of TN and TP from the state would be reduced by 10% and 14% respectively if the BNR-based treatment requirements were implemented.

Total Nitrogen Reduction–***Assuming 65% removal***

9,215 ton TN/yr X 85% of effluent X 65% removal = 5,875 ton/yr removed

5,090/51,000 = 10% reduction in *total* TN export

5,090/9,215 = 55% reduction in PS TN export

Total Phosphorus Reduction–***Assuming 65% removal***

1925 ton TP/yr X 85% of effluent X 65% removal = 1065 ton/yr removed

1065/7,700 = 14% reduction in *total* TP export

1065/1925 = 55% reduction in PS TP export

Assuming a combined point and nonpoint source reduction goal of 30% in the export of both TN and TP, implementation of BNR at the largest Kansas facilities could potentially meet 33% of the goal for TN and 46% of the goal for TP. The remainder of the reductions for TN and TP would be borne by nonpoint sources.

- Nonpoint Source Reductions

Assuming the point source controls discussed above are effective at large WWTFs, nonpoint sources would need to achieve a reduction of 24% in TN to reach the ultimate goal of a 30% overall reduction in TN exported from Kansas. For TP, nonpoint sources would need to achieve a reduction of 22% to reach the ultimate goal of a 30% overall reduction in TP exported from Kansas.

At a minimum, application of accepted nonpoint source best management practices (BMPs) should be addressed in targeted watersheds. Kansas State University has developed a catalog of BMPs and expected nutrient reductions that form the basis for tracking NPS reductions (See Appendix D). The document addresses BMPs for both cropland and livestock waste application.

In order to track NPS reductions, databases of implemented BMPs associated with specific watersheds will need to be maintained by KDHE and the State Conservation Commission.

Coordination among various state and federal agencies involved with BMP implementation will be vital to assess anticipated reductions.

A summary of proposed future point and nonpoint source nutrient distribution reflecting a 30% overall reduction in TN and TP is presented in Table 2.

Table 2 – Current/Future Nutrient Export

	Tons Exiting Kansas Annually			
	Current	**Future**	**% Reduction**	**% of Goal**
TN Total	**51,000**	**35,700**	**30%**	**100%**
PS	9,215	4,125	55%	33%
NPS	41,785	31,575	24%	67%
TP Total	**7,700**	**5,390**	**30%**	**100%**
PS	1,925	860	55%	46%
NPS	5,775	4,530	22%	54%

F. Implementation Plan

The broad implementation of nutrient reduction will be driven by the Kansas *Water Plan*. The Kansas *Water Plan* is the instrument used by the State of Kansas to plan for the management, conservation and development of the water resources of the state. Two key priorities in the current *Water Plan* are watershed protection and restoration, and improved water quality (Kansas Water Office, 2004).

Nutrient reduction is a key element in water quality improvements needed to protect and restore Kansas watersheds, and is addressed specifically in the *Water Quality* section of the Plan:

> "By 2010, reduce the average concentration of bacteria, biochemical oxygen demand, dissolved solids, metals, nutrients, pesticides and sediment that adversely affect the water quality of Kansas lakes and streams."

The *Water Plan* identifies WRAPS - Watershed Restoration and Protection Strategies – as the primary mechanism for improving water quality. The WRAPS approach is a watershed-based planning and management process that utilizes collaborative problem-solving among key stakeholder groups at the local, state, and federal levels. The process involves assessing resource issues and opportunities within a watershed, then developing a plan that outlines goals, objectives and strategies to address priority needs. The plan also identifies resources needed to implement the proposed strategy. This watershed approach has been applied successfully in Kansas and throughout the country.

The WRAPS effort is supported by multiple state and federal agencies, including KDHE, Kansas State University, the Kansas Water Office, the State Conservation Commission, the Kansas Department of Wildlife and Parks, the Kansas Department of Agriculture, the Natural Resources Conservation Service, and the US Army Corps of Engineers. These groups provide technical support to watershed groups in developing their strategies.

Specifically, the WRAPS processes can address both point and nonpoint sources of nutrients under one umbrella effort. WRAPS can identify appropriate strategies for reduction of loads from both point sources and nonpoint sources within each watershed based on stakeholder input.

- Point Sources – Wastewater Treatment Facilities

As indicated in the previous section, it is expected most large (>1 MGD average design flow) municipal wastewater treatment facilities (WWTFs) can meet TN limits of 8 mg/L and TP limits of 1.5 mg/L on an annual average basis with biological nutrient removal (BNR) technology. These are referred to as *technology-based BNR limits*. Nutrient reduction at industrial facilities would have to be evaluated on a case-by-case basis due to the varying nature of their wastewater streams. While it is not anticipated a single technology-based limit would apply to all industrial discharges, nutrient reduction would be required where it is technologically feasible.

Regardless of the source of the wastewater, a key component of the wastewater treatment requirements is the imposition of **annual average** permit limits. Since biological processes are more efficient at higher temperatures, higher quality wastewater effluent is produced in the spring, summer, and fall than in the winter. Thus, while limits may not be met during winter months, data averaged for the year should yield results at or below 8.0 mg/L for TN and 1.5 mg/L for TP.

Coincident with improved nutrient removal during the summer months is the growing season for algae. Algal growth is most robust during the summer months. With wastewater treatment plants discharging fewer nutrients in the summer, there will an added benefit of limiting the nutrients algae need throughout the summer growing season.

It is proposed that technology-based nutrient limitations be phased into municipal WWTF permits over the next 15 years, or three permit cycles. Small facilities (<1 MGD average design flow) would be required to optimize treatment for nutrient removal and evaluate the cost of incorporating technology-based biological nutrient removal if the WWTF is proposed for expansion.

While these technology-based limits would be applied statewide, individual WRAPS could explore alternate requirements as long as an equivalent watershed nutrient reduction was achieved. The concept of trading among nutrient sources will be discussed later.

For industrial wastewater facilities with significant nutrient discharges, schedules of compliance (SOCs) would be incorporated into their next permit (within 5 years). The SOCs would require the industrial permittees to complete engineering studies assessing the efficacy and cost of nutrient removal at the permitted facilities.

Prioritization for phasing in controls for large WWTFs would be based on the expected impact of the point source on downstream waters. Generally, Figures 1 and 4 provide the framework for prioritization. Figure 1 indicates the geographic relationship of large WWTFs to the watersheds' expected TN transport rate. Those facilities located in watersheds with the highest transport rates would be considered high priority and addressed first. Figure 4 indicates the relationship of WWTFs in relation to major Kansas reservoirs. Those facilities with an impact on the major reservoirs, as well as out-of-state reservoirs would also be considered high priority. Added priority will come forth with TMDLs dealing with nutrient impairments.

There are two general mechanisms for implementing the point source nutrient limitations - individual permits or watershed-based nutrient permits. Individual permits are issued for each facility and would have the proposed nutrient limits phased in as current permits expire. Each WWTF would be required to meet the individual permit limits once placed in the permit.

The watershed permit concept has been utilized successfully for TN in North Carolina (USEPA, 2004). A single discharge load from a group of dischargers in a watershed was developed based on a 30% overall nitrogen reduction. As long as the overall limitations are met in the basin, all WWTFs are considered to be in compliance. This method allows WWTFs to "share" their TN loads. In other words, if one WWTF removes nutrients in greater quantity than needed, another WWTF can exceed its quantity by an equal amount, yet all WWTFs in the basin are considered to be in compliance. This allows WWTFs to work together as a group to address nutrients. It may be more economical for one WWTF to pay for excess nutrient removal at a neighboring WWTF than to initiate a WWTF upgrade. It also facilitates trading between point and nonpoint sources of pollution, whereby a point source might fund nutrient reduction for a nonpoint source if that form of nutrient control is more economical. Trading will be discussed in more detail later.

A similar program has been successful in Connecticut, where all drainage eventually affects Long Island Sound (USEPA, 2004). Connecticut utilizes a General Permit to reduce the aggregate point source TN loading to Long Island Sound. Connecticut's goal is to reduce TN by 64%. Similar to North Carolina, the permit allows point sources to meet the requirement as a group as opposed to individual facilities.

To allow maximum flexibility, KDHE would propose watershed-specific general permits. This method would allow WWTFs wishing to combine their allowable nutrient loads to work together to achieve compliance. The method would also provide an impetus for point-to-point source trading, as well as establish a starting point for point-to-nonpoint source trading. WWTFs choosing not to participate in a watershed permit would be covered by an individual permit with technology-based limits.

- Point Sources – Stormwater

No specific reductions have been targeted for municipal or industrial stormwater discharges. Due to the intermittent nature of such discharges and their relatively small contribution to the statewide nutrient load, this document does not address specific reduction targets. It is anticipated, however, that implementation of municipal separate storm sewer system (MS4) permits and industrial stormwater permits will provide some additional unquantifiable benefits to overall nutrient reduction. Further targeting of necessary activities to reduce stormwater will come forth through stream and lake TMDLs.

- Nonpoint Sources

As noted previously, nonpoint sources of nutrients are basically unregulated. Thus, any strategy for nonpoint source reduction would involve voluntary efforts coupled with existing state and federal programs aimed at nonpoint source pollution control.

In order to achieve the maximum benefit for available state and federal funding of nonpoint source nutrient control, identification of vulnerable watersheds where nutrient controls will have the greatest impact must be targeted. Some targeting can be developed by identifying those watersheds where:

+ Total Maximum Daily Load (TMDL) documents have been developed for nutrient impaired lakes and streams (Appendices E and F).

+ Drinking water supply lakes are located (Appendix G).

+ Large amounts of nitrogen and phosphorus fertilizer transport can be predicted (Figures 2, 3 and 5).

+ Excess manure is produced on individual farms (Appendix C).

Concerning the last two bullets, a simple rating system was devised to screen counties based on the relative potential improvement that can be expected from implementation of nonpoint source BMPs.

A scale of one to five (low potential improvement to high potential improvement) was developed for each: 1) phosphorus fertilizer use, 2) excess on-farm manure phosphorus quantity, 3) nitrogen fertilizer use, 4) nitrogen fertilizer transport potential and 5) excess on-farm manure nitrogen quantity.

The nitrogen values and the phosphorus values were combined to calculate *improvement potential index* (IPI) values for nitrogen and phosphorus on a county-by-county basis. The higher the ranking value, the greater the relative potential for improvements produced within that county.

It should be noted the IPI is a *relative* measure. It does not mean a county with an IPI of eight can make twice the improvement of county with an IPI of four. The higher IPI only suggests there is a greater possibility of improvement.

Graphic representations of the results are presented in Figures 6 and 7.

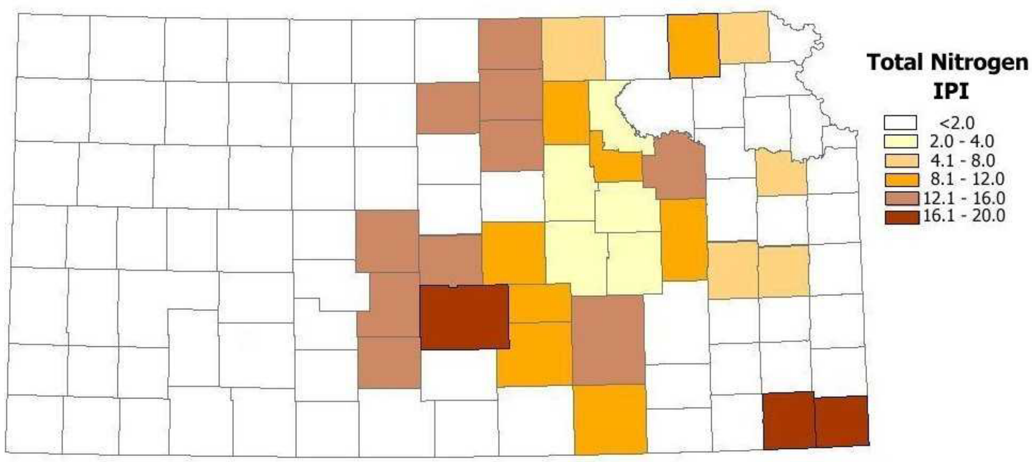

Figure 6 – Improvement Potential Index (IPI) for total nitrogen in surface waters. The darker colors indicate higher the IPI.

Due to the importance of phosphorus impacts on drinking water reservoirs, Figure 7 also indicates the locations of large reservoirs and a scale of the direct population served by a reservoir water supply in each county.

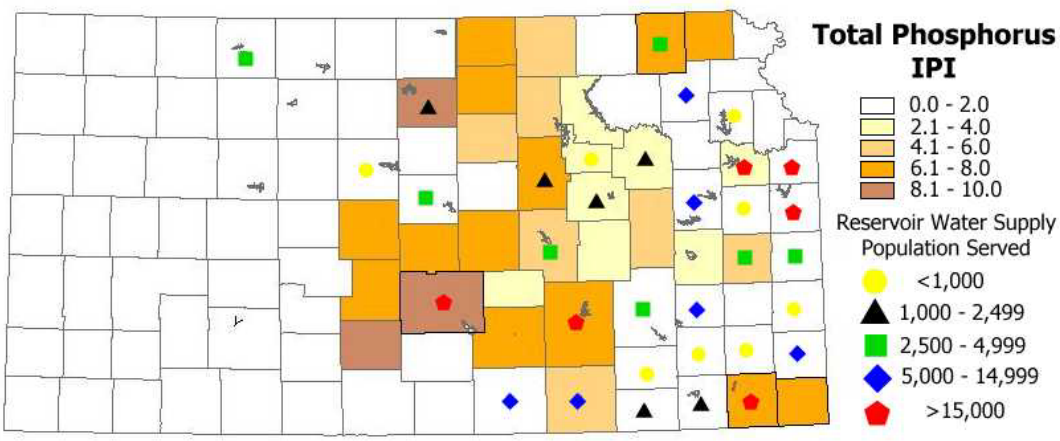

Figure 7 – Improvement Potential Index (IPI) for total phosphorus in surface waters. The darker colors indicate higher the IPI.

Again, the rankings are a screening tool that provides a starting point to focus WRAPS efforts. Enhanced modeling and monitoring efforts would better clarify needed improvements and the effectiveness of those improvements. Some work has been done in the modeling arena, but there are major gaps in watershed analyses. KDHE will continue to pursue additional modeling and targeted monitoring through existing means as well as seeking additional federal 104(b)(3) funding through EPA.

- Point/Nonpoint Source Trading

Nutrient *trading* is a relatively new approach to achieving water quality goals. Trading is predicated on the fact that in some watersheds more than one nutrient source exists. Trading allows an owner of a source facing higher nutrient control costs to purchase equivalent nutrient reductions from another source – either a point source or a nonpoint source - at a lower cost if a lower cost option exists.

For pollutants like nutrients where the impact tends to be a *watershed impact* and not necessarily a problem in the immediate vicinity of the source, equivalent water quality improvement in the watershed can often be achieved at lower overall cost. In other words, it does not make any difference which source reduces nutrients as long as the overall nutrient reduction goal in the watershed is attained.

Kansas does not currently have a formal trading policy. The concept and its potential for use are being explored by Kansas State University's Office of Local Government in cooperation with KDHE. If it is determined there is sufficient demand for a formal trading program, KDHE will work with EPA Region 7 to develop an acceptable program.

- Future criteria

As laid out in this Plan, criteria are not a part of the immediate solution to nutrient reduction. As the bases for criteria become more refined through the WRAPS and TMDL processes, they will be a future consideration, particularly site specific criteria for reservoirs. At a minimum, the status of nutrient criteria will be assessed during the triennial review of the Kansas Surface Water Quality Standards.

VI. Summary

Nutrients are undeniably one of the greatest impediments to achieving improved surface water quality in Kansas. Additionally, nutrients exported from Kansas contribute to water quality problems outside of Kansas' borders. Through eutrophication, nutrients can negatively impact drinking water, recreation and aquatic life uses.

Resolution of nutrient impacts must be shared between point and nonpoint sources. The setting of nutrient criteria at this time, however, would shift nearly the entire burden onto point sources. With the majority of those point sources being Kansas communities of less than 1000 population, resolution through criteria-based permit limits is economically infeasible. Therefore, a more pragmatic approach for nutrient reduction is needed. To this end, Kansas is proposing nutrient reduction targets.

Reduction targets have proven to be the most successful means for addressing nutrients in the US. North Carolina and Connecticut have had remarkable success in meeting nutrient reduction targets in the absence of nutrient criteria.

The reduction targets for Kansas, set at 30% for both total nitrogen and total phosphorus, are based on minimizing both in-state and out-of-state impacts. By coupling nutrient reduction from the largest Kansas wastewater dischargers with best management practices for nonpoint sources, these targets can be met and exceeded.

Kansas already has the policy infrastructure in place to address nutrients as a high level priority. The *Kansas Water Plan* currently acknowledges nutrients as a major water issue facing Kansas. Through the Watershed Restoration and Protection Strategies (WRAPS) and designated high priority TMDLS, local, state and federal stakeholders can identify and implement the actions necessary to make meaningful, lasting improvements to water quality in Kansas.

Lastly, implementation of this Plan would place Kansas in a leadership position in addressing the nationwide quandary of surface water nutrient pollution – leading by example.

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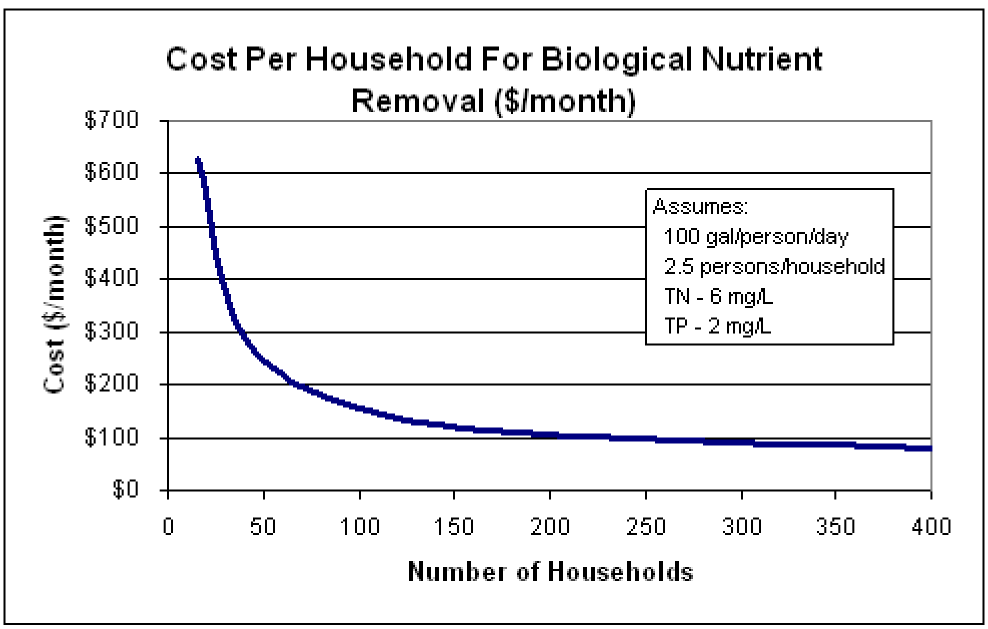
Appendix A

Nutrient Removal Treatment Costs

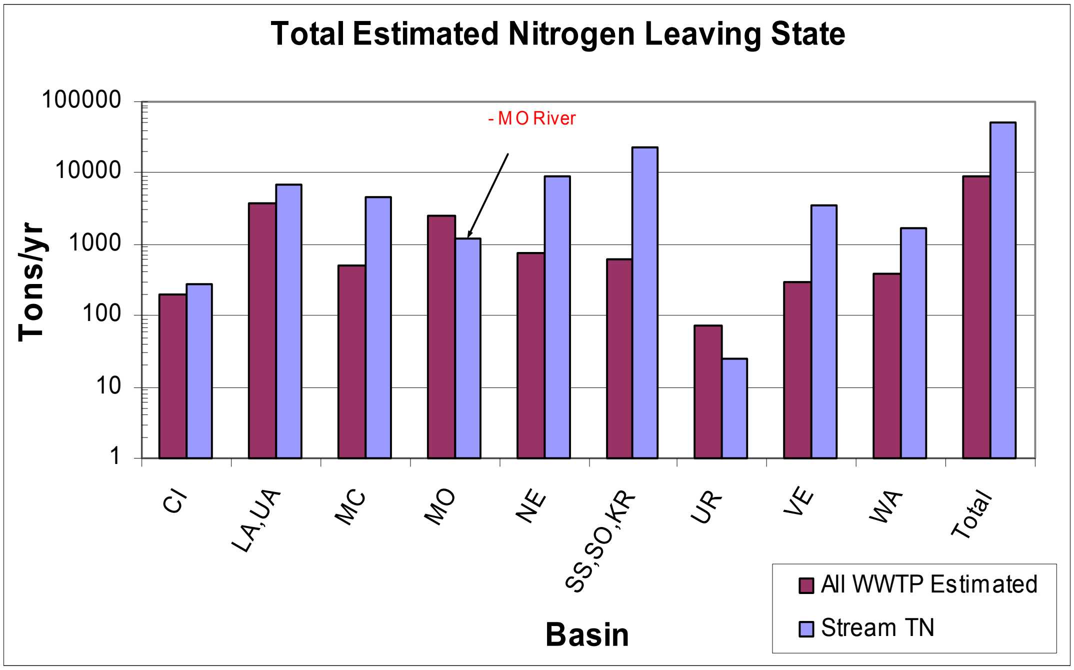
3-Stage BNR Treatment Cost

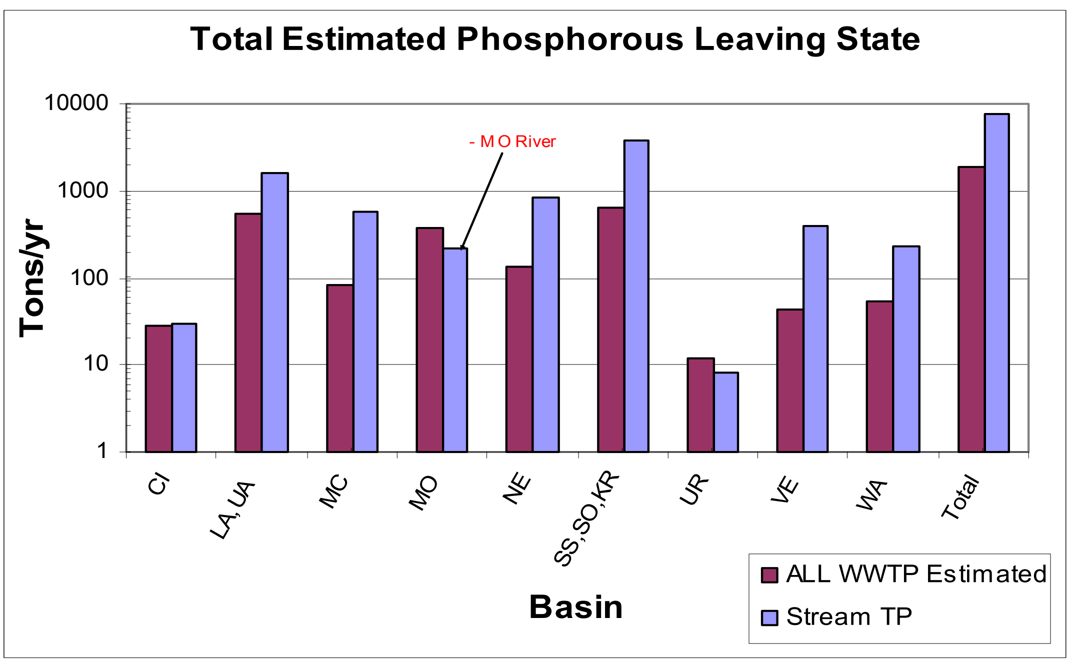
	Waste Treated (gpd)				
	4,000	10,000	25,000	50,000	100,000
Cost ($/1000 gallon)	71.2	32.9	17.6	12.2	9.1
Cost/person/month	$217	$100	$54	$37	$28
Cost/connection/month*	$541	$250	$134	$93	$69
*Assume 2.5 per connection					
Persons	40	100	250	500	1000
Households	16	40	100	200	400
Inflated cost at 3% inflation	$628	$290	$155	$108	$80



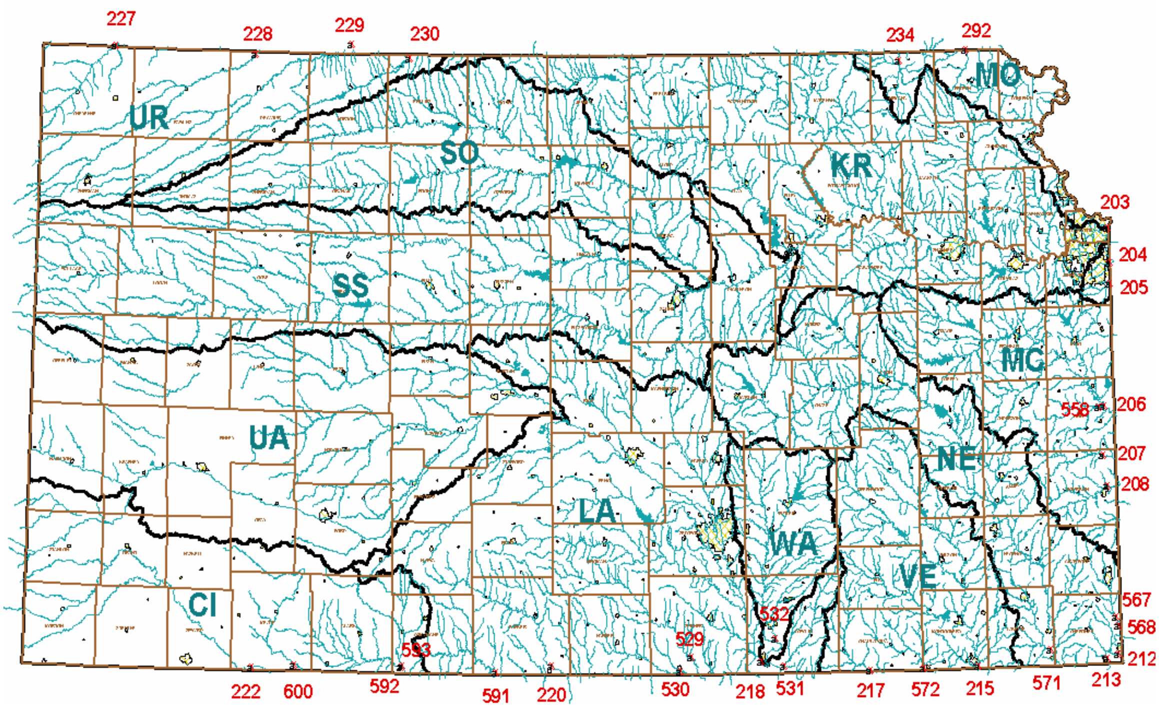
Appendix B

Basin Data and Sample Sites


Total Estimated Nitrogen Leaving State
Tons/yr
100000
10000
1000
100
10
1
- M O River
CI
LA,UA
MC
MO
NE
SS,SO,KR
UR
VE
WA
Total
Basin
All WWTP Estimated
Stream TN


Total Estimated Phosphorous Leaving State
Tons/yr
10000
1000
100
10
1
- M O River
CI
LA,UA
MC
MO
NE
SS,SO,KR
UR
VE
WA
Total
Basin
ALL WWTP Estimated
Stream TP

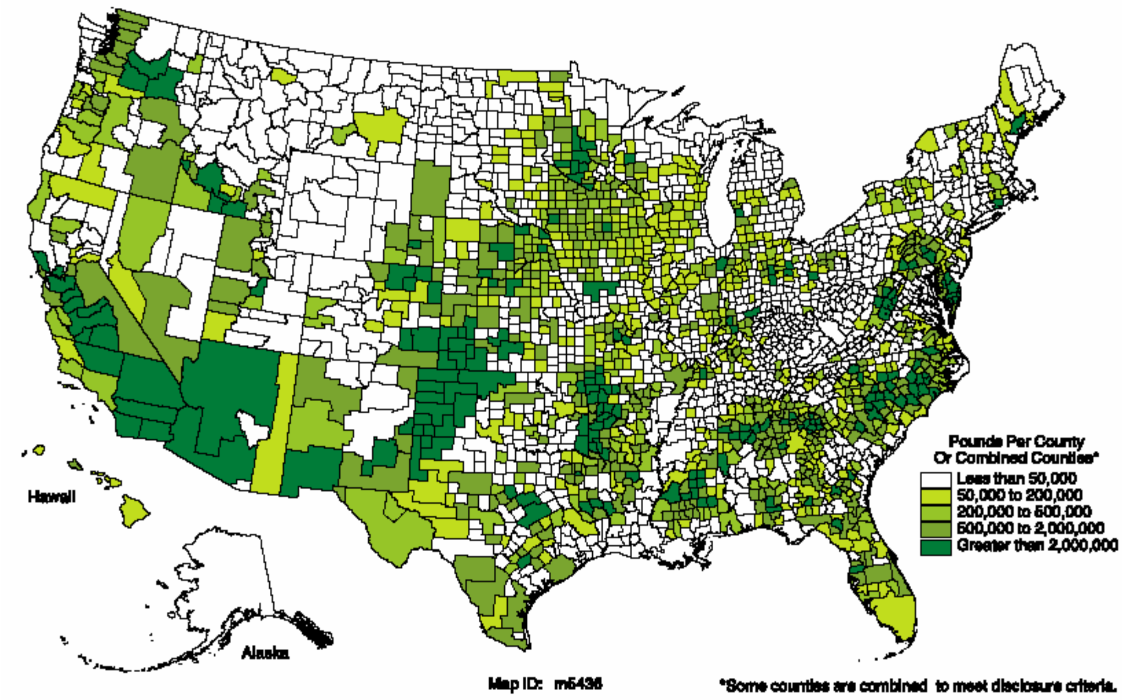
Kansas Stream Chemistry Monitoring Sites



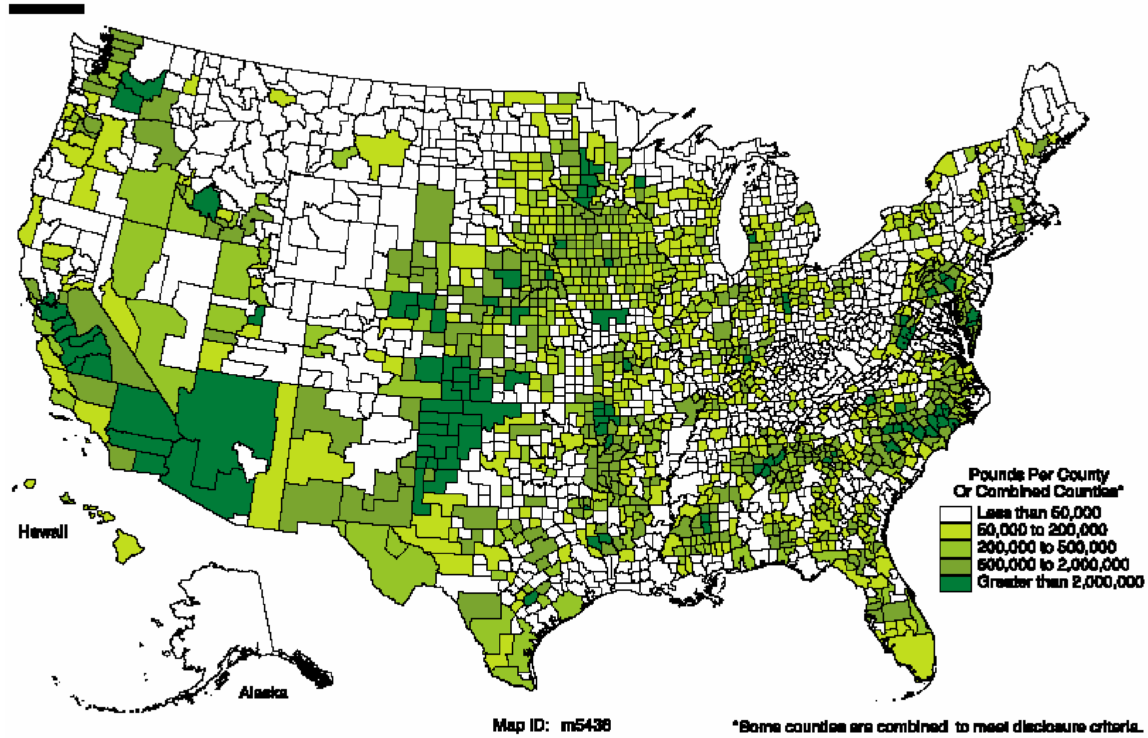
Appendix C

USDA Manure Data – Farms With Excess Manure

Map 28 Excess manure nitrogen assuming no export of manure from farm, 1997



Map 30 Excess manure phosphorus assuming no export of manure from farm, 1997



Appendix D

Agriculture Best Management Practices

Water Quality Best Management Practices, Effectiveness, and Cost for Reducing Contaminant Losses from Cropland

Kansas State University
Department of Agronomy &
Department of Agricultural Economics
MF-2572
Water Quality

K-State Research and Extension faculty have conducted field, laboratory, and computer modeling studies on the effect of crop management practices and land application of livestock waste on the runoff of pesticides, nutrients, and sediments/suspended solids from crop fields. This publication lists recommended best management practices (BMP) for conventional and no-till cropping systems and for land application of livestock waste. This publication also shows the effectiveness of a BMP in reducing runoff of a contaminant, and an estimated cost of implementing BMPs.

The percent reduction in runoff by adopting a listed BMP is the effectiveness obtained from adoption of a single new BMP. It is not appropriate to consider the effectiveness of the adoption of several BMPs to be additive.

A reported BMP cost is the expected loss in producer profitability associated with adoption. Alternatively, it can be treated as the payment-to-producer required to induce adoption. BMP costs and effectiveness figures are based on research, farm data, and professional estimates.

Conventional Tillage

The table on page 2 contains the cost and effectiveness of reducing the runoff of contaminants from the adoption of various BMPs under conventional tillage systems.

The data on reduction of runoff by adopting a BMP are relative to a corn and grain sorghum field where atrazine herbicide is applied preemergence (herbicide broadcast, surface applied following crop planting, but prior to crop emergence), phosphorus and nitrogen fertilizer broadcast applied prior to planting the crop and unincorporated, conventional tillage (less than 30 percent residue cover following planting), with greater than 1 percent slope on upland clay or clay loam soils. For wheat and other crops, the comparison benchmark is phosphorus and nitrogen fertilizer broadcast applied, unincorporated, conventional tillage, with greater than 1 percent slope on upland clay or clay loam soils.

No-till

The table on page 3 contains the cost and effectiveness of reducing the runoff of contaminants from the adoption of various BMPs in a no-till system. The data on reduction of runoff by adopting a BMP are relative to a no-till corn and grain sorghum field where atrazine herbicide is applied preemergence (herbicide broadcast, surface applied following crop planting but prior to crop emergence), phosphorus and nitrogen fertilizer broadcast applied prior to planting the crop, with greater than 1 percent slope on upland clay or clay loam soils. For wheat and other crops, the comparison benchmark is phosphorus and nitrogen fertilizer broadcast applied, unincorporated, no-till prior to planting the crop, with greater than 1 percent slope on upland clay or clay loam soils.

Additional Best Management Practices for Livestock Waste Applications to Cropland

The table on page 4 contains the cost and effectiveness of various BMPs for reducing the runoff of contaminants associated with the application of livestock waste. The data on reduction of runoff by adopting a BMP are relative to livestock waste application broadcast applied in summer months without incorporation to conventionally tilled fields, with greater than 1 percent slope on upland clay or clay loam soils.

Best Management Practice for Conventional Tillage	Cost/Acre ($)	Atrazine Herbicide	Nutrients: Soluble Phosphorus	Nutrients: Total Phosphorus	Nutrients: Nitrogen	Suspended Solids
		-------------- (percent reduction in runoff by adopting BMP) --------------				
Preplant incorporate into the top two inches of soil prior to the first runoff	7.15	70	60	20	50	0
Use postemergence herbicide applications	6.02	50	0	0	0	0
Use alternative herbicides	10.12	100	0	0	0	0
Use in-season cultivation to minimize herbicide use	15.93	30	0	0	0	0
Band herbicides, nitrogen, and phosphorus on the soil surface prior to or at planting; typically 30 percent surface area, weeds between rows controlled with cultivation	3.40	50	20	20	25	0
Subsurface apply phosphorus or nitrogen fertilizer	3.50	0	60	30	60	0
Apply atrazine in fall for next year's row crop	8.34	50	0	0	0	0
Apply herbicide in early spring, prior to May 1	5.56	50	0	0	0	0
Use split applications of herbicide, e.g., ½ to ⅔ prior to May 1 and ½ to ⅓ at planting	6.02	25	0	0	0	0
Use reduced soil-applied herbicide application rates followed by a postemergence application	6.02	33	0	0	0	0
Crop rotations	0	30	25	25	25	25
Establish vegetative buffer strips	a/	25	25	50	35	50
Do not spray/apply herbicides or nutrients within 100 feet of streams or near where runoff enters a stream	b/	20	25	25	25	0
Use weed scouting/integrated pest management	5.00	0 - 50	0	0	0	0
Conservation tillage farming (>30 percent residue cover following planting)	0	20	0	35	15	30
No-till farming	0	0	0	40	25	75
Contour farming (without terraces)	6.80	20	20	30	20	35
Terraces with tile outlets	c/	10	10	30	10	30
Terraces with grass waterways (with contour farming)	d/	30	30	30	30	30
Soil sampling and testing	1.00	0	0 - 25	0 - 25	0 - 25	0
Sound fertilizer recommendations	0	0	0 - 25	0 - 25	0 - 25	0

[a] Establishment cost of $100 per acre plus an annual cost equal to the average per acre land rental rate for the acreage within the vegetative buffer strip.
[b] Annual cost equal to the average per acre land rental rate for the acreage where herbicides and nutrients are not applied (i.e., acres within 100 feet of streams or before runoff enters a stream).
[c] One-time installation cost of $40 per acre plus an annual cost of $13.60 per acre.
[d] One-time installation cost of $30 per acre plus an annual cost of $13.60 per acre (all crop acres in the field) plus an annual cost equal to the average per acre land rental rate for the acreage within the grass waterways.

Best Management Practice for No-till	Cost/Acre ($)	Atrazine Herbicide	Nutrients			Suspended Solids
			Soluble Phosphorus	Total Phosphorus	Nitrogen	
		(percent reduction in runoff by adopting BMP)				
Use postemergence herbicide applications	6.02	50	0	0	0	0
Use alternative herbicides	10.12	100	0	0	0	0
Use in-season cultivation to minimize herbicide use	15.93	30	0	0	0	0
Band herbicides, nitrogen, and phosphorus on the soil surface prior to or at planting; typically 30 percent surface area, weeds between rows controlled with cultivation	3.40	50	20	20	25	0
Subsurface apply phosphorus or nitrogen fertilizer	3.50	0	70	50	70	0
Apply atrazine in fall for next year's row crop	8.34	50	0	0	0	0
Apply herbicide in early spring, prior to May 1	5.56	50	0	0	0	0
Use split applications of herbicide, e.g., ½ to ⅔ prior to May 1 and ½ to ⅓ at planting	6.02	25	0	0	0	0
Use reduced soil-applied herbicide application rates followed by a postemergence application	6.02	33	0	0	0	0
Crop rotations	0	30	25	25	25	25
Establish vegetative buffer strips	a/	25	25	50	35	50
Do not spray/apply herbicides or nutrients within 100 feet of streams or near where runoff enters a stream	b/	20	25	25	25	0
Use weed scouting/integrated pest management	5.00	0 - 50	0	0	0	0
Contour farming (without terraces)	6.80	20	20	30	20	20
Terraces with tile outlets	c/	10	10	30	10	30
Terraces with grass waterways (with contour farming)	d/	30	30	30	30	30
Soil sampling and testing	1.00	0	0 - 25	0 - 25	0 - 25	0
Sound fertilizer recommendations	0	0	0 - 25	0 - 25	0 - 25	0

[a] Establishment cost of $100 per acre plus an annual cost equal to the average per acre land rental rate for the acreage within the vegetative buffer strip.
[b] Annual cost equal to the average per acre land rental rate for the acreage where herbicides and nutrients are not applied (i.e., acres within 100 feet of streams or where runoff enters a stream).
[c] One-time installation cost of $40 per acre plus an annual cost of $13.60 per acre.
[d] One-time installation cost of $30 per acre plus an annual cost of $13.60 per acre (all crop acres in the field) plus an annual cost equal to the average per acre land rental rate for the acreage within the grass waterways.

Best Management Practices for Livestock Waste Applications to Cropland	Cost/Acre ($)	Fecal Coliform Bacteria	Nutrients			Suspended Solids
			Soluble Phosphorus	Total Phosphorus	Nitrogen	
		-------------- (percent reduction in runoff by adopting BMP) --------------				
Incorporate with tillage equipment	7.15	90	70	20	50	0
Subsurface inject liquid waste	25.50	90	70	20	50	0
No-till farming	0	60	0	40	0	60
Conservation tillage farming	0	50	0	35	0	50
Test livestock waste for nutrient value	1.00	0	0 - 30	0 - 30	0 - 30	0

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MF-2572 February 2003

Appendix E

Eutrophication Status of Lakes on the Kansas Surface Water Register

Key: Black text – Lake Compliant	Blue text – Lake 303d listed	Red text – Lake TMDL developed

Those lakes with developed or anticipated (listed) TMDLs that are going to be high priority for implementation are noted in bold text.

Kansas Lower Republican Basin Lakes	County	Compliant, Listed or TMDL
MIDDLE REPUBLICAN (HUC 10250016)		
Lovewell Lake	Jewell	Listed
LOWER REPUBLICAN (HUC 10240017)		
Milford W.A.	Clay	Compliant
LOWER REPUBLICAN (HUC 10250017)		
Belleville City Lake	Republic	TMDL
Jamestown W.A.	Cloud	TMDL
Lake Jewell	Jewell	TMDL
Milford Lake	**Geary**	**Listed**
Rimrock Park Lake	Geary	TMDL
Wakefield Lake	Clay	Compliant
UPPER KANSAS (HUC 10270101)		
Ogden City Lake	Riley	TMDL
MIDDLE KANSAS (HUC 10270102)		
Pillsbury Crossing W.A.	Riley	Compliant
Cedar Crest Lake	Shawnee	Compliant
Central Park Lake	Shawnee	TMDL
Dornwood Park Lake	Shawnee	Compliant
Gage Park Lake	Shawnee	TMDL
Lake Jivaro	Shawnee	Compliant
Lake Shawnee	Shawnee	Listed
Lake Sherwood	Shawnee	Compliant
Myer's Lake	Shawnee	TMDL
Shawnee Co. SFL	Shawnee	Compliant
Topeka Public Golf Course Lake	Shawnee	Compliant
Warren Park Lake	Shawnee	TMDL
Washburn Rural Environmental Lab Lake	Shawnee	Compliant
Alma City Lake	Wabaunsee	Compliant
Wabaunsee Co. Lake	Wabaunsee	Listed
Wamego City Lake	Pottawatomie	TMDL
Jeffrey Energy Center W.A.	Pottawatomie	Compliant
Pottawatomie Co. SFL #1	Pottawatomie	Listed
DELAWARE (HUC 10270103)		
Atchison Co. Park Lake	Atchison	Listed
Muscotah Marsh	Atchison	Compliant
Banner Creek Lake	Jackson	Listed
Elkhorn Lake	Jackson	Compliant
Nebo SFL	Jackson	Compliant
Prairie Lake	Jackson	Compliant
Sabetha Watershed Lake (Niehues)	Nemaha	TMDL
Mission Lake	**Brown**	**TMDL**
Little Lake	Brown	TMDL
Lake Jayhawk	Jefferson	Listed
Oskaloosa Lake	Jefferson	Compliant
Perry Lake	**Jefferson**	**Listed**
Perry W.A.	**Jefferson**	**Listed**

Kansas-Lower Republican Basin Lakes	**County**	**Compliant, Listed or TMDL**
LOWER KANSAS (HUC 10270104)		
Lenexa Lake (Rose’s Lake)	Johnson	Listed
Antioch Park Lake	Johnson	Compliant
Cedar Lake	Johnson	TMDL
Frisco Lake	Johnson	TMDL
Gardner City Lake	**Johnson**	**TMDL**
Mahaffie Farmstead Lake	Johnson	Compliant
Nagiwika	Johnson	Compliant
New Olathe Lake	**Johnson**	**Listed**
Olathe Waterworks Lakes	Johnson	TMDL
Shawnee Mission Lake	Johnson	Compliant
Sunflower Park Lake	Johnson	TMDL
Baker Wetlands	**Douglas**	**TMDL**
Clinton Lake	**Douglas**	**TMDL**
Douglas Co. SFL	Douglas	Listed
Lone Star Lake	Douglas	TMDL
Mary's Lake	Douglas	TMDL
Potter's Lake	Douglas	TMDL
Carbondale West Lake	Osage	Compliant
Strowbridge Reservoir	Osage	Compliant
Lakeview Estates Lake	Shawnee	TMDL
Lake Dabanawa	Jefferson	Compliant
Leavenworth Co. SFL	Leavenworth	Listed
Lake Quivera	Wyandotte	Compliant
North Park Lake	Wyandotte	Compliant
Pierson Park Lake	Wyandotte	TMDL
LOWER BIG BLUE (HUC 10270205)		
Centralia Lake	Nemaha	TMDL
Pottawatomie Co. SFL #2	Pottawatomie	Compliant
Rocky Ford W.A.	Riley	Compliant
Tuttle Creek Lake	**Riley**	**TMDL**
Tuttle Creek WA	Riley	Compliant
LOWER LITTLE BLUE (HUC 10270207)		
Lake Idlewild	Marshall	TMDL
Washington Co. SFL	Washington	TMDL
Washington W.A.	Washington	TMDL

Lower Arkansas Basin Lakes	County	Compliant, Listed or TMDL
RATTLESNAKE (HUC 11030009)		
Kiowa Co. SFL	Kiowa	Listed
Quivira Big Salt Marsh	**Stafford**	**TMDL**
Quivira Little Salt Marsh	**Stafford**	**TMDL**
GAR-PEACE (HUC11030010)		
Carey Park Lake	Reno	TMDL
COW (HUC 11030011)		
Barton Lake	Barton	Compliant
Cheyenne Bottoms	**Barton**	**TMDL**
Sterling City Lake	Rice	Listed
LITTLE ARKANSAS (HUC 11030012)		
Dillon Park Lakes	Reno	TMDL
Harvey Co. Camp Hawk Lake	Harvey	TMDL
Harvey Co. West Park Lake	Harvey	TMDL
Newton City Park Lake	Harvey	TMDL
Inman Lake	McPherson	Compliant
McPherson Wetlands	McPherson	Compliant
Mingenback Lake	McPherson	TMDL
MIDDLE ARKANSAS-SLATE (HUC 11030013)		
Buffalo Park Lake	Sedgwick	Compliant
Cadillac Lake (Pracht Wetland)	Sedgwick	TMDL
Chisholm Creek Park Lake	Sedgwick	Listed
Eagle Lake (Belaire Lake)	Sedgwick	Compliant
Emery Park Lake	Sedgwick	Compliant
Harrison Park Lake	Sedgwick	Compliant
Horseshoe Lake	Sedgwick	TMDL
Kid's Lake	Sedgwick	TMDL
Moss Lake	Sedgwick	Compliant
Riggs Park Lake	Sedgwick	Compliant
Vic's Lake	Sedgwick	Listed
Watson Park Lake	Sedgwick	TMDL
Windmill Lake	Sedgwick	Compliant
Slate Creek W.A.	Sumner	TMDL
NORTH FORK NINNESCAH (HUC 11030014)		
Cheney Lake	Reno	TMDL
SOUTH FORK NINNESCAH (HUC 11030015)		
Kingman Co. SFL	Kingman	TMDL
Kingman W.A.	Kingman	Listed
KWP Hatchery and Ponds	Pratt	Compliant
Lemon Park Lake	Pratt	Listed
Pratt Co. Lake	**Pratt**	**TMDL**
Texas Lake W.A.	Pratt	Listed
NINNESCAH (HUC 11030016)		
Lake Afton	**Sedgwick**	**TMDL**
KAW LAKE (HUC 11060001)		
Cowley Co. SFL	Cowley	Listed
Kaw W.A.	Cowley	Compliant
MEDICINE LODGE (HUC 11060003)		
Barber Co. SFL	Barber	TMDL

Lower Arkansas Basin Lakes	**County**	**Compliant, Listed or TMDL**
CHIKASKIA (HUC 11060005)		
Anthony City Lake	**Harper**	**Listed**
Isabel W.A.	Pratt	TMDL
Hargis Lake	Sumner	TMDL
Wellington Lake	Sumner	Compliant
Wellington New City Lake	Sumner	Compliant

Upper Arkansas Basin Lakes	**County**	**Compliant, Listed or TMDL**
MIDDLE ARKANSAS-LAKE MCKINNEY (HUC 11030001)		
Beymer Lake	Kearney	Compliant
Hamilton Co. SFL	Hamilton	TMDL
Hamilton W.A.	Hamilton	TMDL
ARKANSAS-DODGECITY (HUC 11030003)		
Lake Charles	Ford	Listed
PAWNEE (HUC 11030005)		
Concannon SFL	Finney	Listed
Finney Co. SFL/W.A.	Finney	Compliant
BUCKNER (HUC 11030006)		
Ford Co. Lake	**Ford**	**TMDL**
Hain SFL	Ford	Compliant
Hodgeman Co. SFL/W.A.	Hodgeman	TMDL
Jetmore Lake	Hodgeman	Listed
Boy Scout Lake	Hodgeman	Listed
LOWER WALNUT CREEK (HUC 11030008)		
Goodman SFL	Ness	Compliant
Memorial Park Lake	Barton	Listed
Stone Lake	Barton	TMDL

Cimarron Basin Lakes	**County**	**Compliant, Listed, or TMDL**
UPPER CIMARRON (HUC 11040002)		
Cimarron Lake (Moss Lake Middle)	Morton	Compliant
Mallard Lake (Moss Lake East)	Morton	Compliant
Point of Rocks Lake (Moss Lake West)	Morton	Compliant
CROOKED CREEK (HUC 11040007)		
Lake Meade State Park	**Meade**	**TMDL**
Meade Co. State Park W.A.	Meade	Compliant
UPPER CIMARRON-BLUFF (HUC 11040008)		
Clark Co. SFL	Clark	Compliant
St. Jacobs Well (Big Basin W.A.)	**Clark**	**TMDL**
Lake Coldwater	Comanche	Listed

Marais des Cygnes Basin Lakes	**County**	**Compliant, Listed or TMDL**
UPPER MARAIS DES CYGNES (HUC 10290101)		
Cedar Creek Lake	Anderson	Listed
Crystal Lake	Anderson	TMDL
Garnett North Lake	Anderson	Listed
Westphalia Lake	Anderson	Compliant
Harveyville Lake	Wabaunsee	Compliant
Hole In The Rock	Douglas	Compliant
Spring Creek Park Lake	Douglas	TMDL
Lebo City Lake	Coffey	Compliant
Lebo City Park Lake	Coffey	TMDL
Lyndon City Lake	Osage	Compliant
Melvern Lake	Osage	Compliant
Melvern W.A.	Osage	Compliant
Osage City Reservoir	Osage	TMDL
Osage Co. SFL	Osage	Compliant
Pomona Lake	**Osage**	**TMDL**
Scranton City Lake	Osage	Compliant
Osawatomie City Lake	Miami	Compliant
Richmond City Lake	Franklin	Compliant
Lyon Co. SFL	Lyon	Compliant
LOWER MARAIS DES CYGNES (HUC 10290102)		
Blue Mound City Lake	Linn	Listed
La Cygne Lake	Linn	Listed
Marais Des Cygnes N.W.R.	**Linn**	**TMDL**
Marais Des Cygnes W.A.	**Linn**	**TMDL**
Mound City Lake	Linn	TMDL
Parker City Lake	Linn	Compliant
Pleasanton Lake #1	Linn	Listed
Pleasanton Lake #2	Linn	Compliant
Pleasanton Reservoir	Linn	Listed
Edgerton City Lake	Johnson	TMDL
Spring Hill City Lake	Johnson	Compliant
Hillsdale Lake	**Miami**	**TMDL**
Louisburg Old Lake	Miami	Listed
Louisburg SFL	Miami	Listed
Miami Co. SFL	Miami	TMDL
Miola Lake	Miami	Compliant
Paola City Lake	Miami	Compliant
LITTLE OSAGE (HUC 10290103)		
Prescott City Lake	Linn	TMDL
MARMATON (HUC 10290104)		
Bone Creek Lake	Crawford	Compliant
Frisco Lake	Crawford	Compliant
Lake Crawford State Park #2	Crawford	Listed
Bourbon Co. SFL	Bourbon	Listed
Bronson City Lake	Bourbon	TMDL
Elm Creek Lake	Bourbon	TMDL
Fort Scott City Lake	Bourbon	Compliant
Gunn Park East Lake	Bourbon	Compliant
Gunn Park West Lake	Bourbon	Listed
Rock Creek Lake	**Bourbon**	**Listed**

Missouri Basin Lakes	County	Compliant, Listed or TMDL
TARKIO-WOLF (HUC 10240005)		
Brown Co. SFL	Brown	TMDL
Hiawatha City Lake	Brown	TMDL
Troy Fair Lake	Doniphan	TMDL
SOUTH FORK BIG NEMAHA (HUC 10240007)		
Nemaha Co. SFL/W.A.	Nemaha	Compliant
Sabetha City Lake	Nemaha	TMDL
BIG NEMAHA (HUC 10240008)		
Pony Creek Lake	**Brown**	**TMDL**
INDEPENDENCE-SUGAR (HUC 10240011)		
Atchison Co. SFL	Atchison	TMDL
Lake Warnock (Atchison City Lake)	Atchison	Listed
Wyandotte Co. Lake	Wyandotte	Listed
Big Eleven Lake	Wyandotte	TMDL
Jerry's Lake	Leavenworth	Listed
Lansing City Lake	Leavenworth	TMDL
Merrit Lake	Leavenworth	Compliant
Smith Lake	Leavenworth	Compliant
LOWER MISSOURI-CROOKED (HUC 10300101)		
Heritage Park Lake	Johnson	Listed
Prairie View Park Lake	Johnson	Compliant
South Park Lake	Johnson	TMDL
Stanley RWD#2 Lake	Johnson	Compliant
Stohl Park Lake	Johnson	Compliant

Upper Republican Basin Lakes	County	Compliant, Listed or TMDL
SOUTH FORK REPUBLICAN (HUC 10250003)		
Saint Francis W.A.	Cheyenne	Compliant
SOUTH FORK BEAVER (HUC 10250012)		
Atwood Township Lake	Rawlins	Compliant
PRAIRIE DOG (HUC 10250015)		
Colby City Lake	Thomas	TMDL
Norton Lake (Sebelius Lake)	Norton	TMDL
Norton Lake W.A.	Norton	Compliant

Smoky Hill – Saline Basin Lakes	**County**	**Compliant, Listed or TMDL**
NORTH FORK SMOKY HILL (HUC 10260002)		
Sherman Co. SFL/W.A.	Sherman	Compliant
Smoky Hill Garden Lake	Sherman	TMDL
UPPER SMOKY HILL (HUC 10260003)		
Cedar Bluff Lake	Trego	TMDL
Logan Co. SFL	Logan	Compliant
LADDER (HUC 10260004)		
Lake Scott State Park	**Scott**	**TMDL**
MIDDLE SMOKY HILL (HUC 10260006)		
Fossil Lake	Russell	TMDL
Kanopolis Lake	**Ellsworth**	**TMDL**
BIG (HUC 10260007)		
Big Creek Oxbow	Ellis	TMDL
Ellis City Lake	Ellis	TMDL
LOWER SMOKY HILL (HUC 10260008)		
Geary Co. SFL	Geary	TMDL
Herington City Lake	Dickinson	TMDL
Herington City Park Lake	Dickinson	TMDL
Herington Reservoir	**Dickinson**	**TMDL**
Lakewood Park Lake	Saline	TMDL
McPherson Co. SFL	McPherson	TMDL
UPPER SALINE (HUC 10260009)		
Plainville Township Lake	Rooks	TMDL
Sheridan W.A.	Sheridan	Compliant
Wilson Lake	Russell	Compliant
LOWER SALINE (HUC 10260010)		
Saline Co. SFL	Saline	Compliant

Solomon Basin Lakes	**County**	**Compliant, Listed or TMDL**
UPPER NORTH FORK SOLOMON (HUC 10260011)		
Kirwin Lake	Phillips	TMDL
Kirwin N.W.R.	Phillips	Compliant
Logan City Lake	Phillips	TMDL
LOWER NORTH FORK SOLOMON (HUC 10260012)		
Francis Wachs W.A.	Smith	Compliant
UPPER SOUTH FORK SOLOMON (HUC 10260013)		
Antelope Lake	Graham	Compliant
Sheridan Co. SFL	Sheridan	TMDL
Webster Lake	Rooks	TMDL
LOWER SOUTH FORK SOLOMON (HUC 10260014)		
Rooks Co. SFL	Rooks	TMDL
SOLOMON RIVER (HUC 10260015)		
Jewell Co. SFL	Jewell	Listed
Ottawa Co. SFL	Ottawa	TMDL
Waconda Lake	Mitchell	TMDL

Neosho Basin Lakes	County	Compliant, Listed or TMDL
NEOSHO HEADWATERS (HUC 11070201)		
Council Grove City Lake	Morris	Compliant
Council Grove Lake	**Morris**	**TMDL**
Lake Kahola	Morris	Compliant
Flint Hills N.W.R.	Coffey	Compliant
John Redmond Lake	Coffey	TMDL
Jones Park Lake	Lyon	TMDL
Olpe City Lake	**Lyon**	**TMDL**
UPPER COTTONWOOD (HUC 11070202)		
Hillsboro City Lake	Marion	Compliant
Marion Co. Lake	Marion	TMDL
Marion Lake	**Marion**	**TMDL**
Marion W.A.	Marion	Compliant
LOWER COTTONWOOD (HUC 11070203)		
Chase Co. SFL	Chase	Compliant
Peter Pan Lake	Lyon	Compliant
UPPER NEOSHO (HUC 11070204)		
Chanute Santa Fe Lake	Neosho	TMDL
Gridley City Lake	Coffey	TMDL
John Redmond W.A.	Coffey	Compliant
New Strawn Park Lake	Coffey	Compliant
Wolf Creek Lake	Coffey	Compliant
Iola City Lake	Allen	Compliant
Circle Lake	Woodson	Compliant
Leonard's Lake	Woodson	Compliant
Neosho Falls City Lake	Woodson	Compliant
Yates Center Reservoir	Woodson	Compliant
MIDDLE NEOSHO (HUC 11070205)		
Altamont City Main Lake (#1)	Labette	TMDL
Altamont City West Lake (#3)	Labette	Compliant
Bartlett City Lake	Labette	TMDL
Harmon W.A.	Labette	Compliant
Mined Land Lakes 10 - 14	Cherokee	Compliant
Mined Land Lakes 17 - 25	Cherokee	Listed
Mined Land Lakes 27 - 45	Cherokee	Listed
Mined Land Lake No. 42 Wetland	Cherokee	TMDL
Neosho Co. SFL	Neosho	TMDL
Neosho W.A.	Neosho	TMDL
Parsons Lake	Neosho	TMDL
Timber Lake	Neosho	Compliant
SPRING (HUC 11070207)		
Mined Land Lake 09	Cherokee	Compliant
Mined Land Lake 15	Cherokee	Compliant
Empire Lake	Cherokee	Compliant
Mined Land Lakes 01 - 08	Crawford	Listed
Pittsburg College Lake	Crawford	TMDL
Playter's Lake	Crawford	TMDL

Verdigris Basin Lakes	**County**	**Compliant, Listed or TMDL**
UPPER VERDIGRIS (HUC 11070101)		
Eureka Lake	Greenwood	Listed
Madison City Lake	Greenwood	Compliant
Toronto W.A.	Greenwood	Compliant
New Yates Center Lake	Woodson	Compliant
Toronto Lake	**Woodson**	**Listed**
Woodson Co. SFL	Woodson	Compliant
Woodson W.A.	Woodson	TMDL
Thayer New City Lake	Neosho	Compliant
Thayer Old City Lake	Neosho	Compliant
Wilson Co. SFL	Wilson	TMDL
Quarry Lake	Wilson	Compliant
FALL (HUC 11070102)		
Fall River Lake	**Greenwood**	**Listed**
Fall River W.A.	Greenwood	Compliant
Otis Creek Lake (Eureka)	Greenwood	Compliant
Severy City Lake	Greenwood	Compliant
MIDDLE VERDIGRIS (HUC 11070103)		
Big Hill Lake	**Labette**	**Listed**
Edna City Lake	Labette	Compliant
Montgomery Co. SFL	Montgomery	TMDL
La Claire Lake	Montgomery	TMDL
Lake Tanko (Cherryvale City Lake)	Montgomery	TMDL
ELK (HUC 11070104)		
Elk City Lake	**Montgomery**	**Listed**
Elk City W.A.	Montgomery	Compliant
Moline City #1 (Santa Fe Lake)	Elk	Compliant
Moline City Lake #2	Elk	Compliant
Moline Reservoir	Elk	Compliant
Polk Daniels Lake (Elk Co. SFL)	Elk	Listed
CANEY (HUC 11070106)		
Copan W.A.	Montgomery	Compliant
Caney City Lake	Chautauqua	Compliant
Murray Gill Lake	Chautauqua	Compliant
Sedan City North Lake	Chautauqua	Compliant
Sedan City South Lake	Chautauqua	Compliant

Walnut Basin Lakes	**County**	**Compliant, Listed or TMDL**
UPPER WALNUT RIVER (HUC 11030017)		
Harvey Co. East Lake	Harvey	TMDL
Augusta City Lake	Butler	Listed
Augusta Santa Fe Lake	Butler	TMDL
El Dorado Lake	**Butler**	**TMDL**
LOWER WALNUT RIVER (HUC 11030018)		
Butler Co. SFL	Butler	TMDL
Winfield City Lake	**Cowley**	**Listed**
Winfield Park Lagoon	Cowley	TMDL

Appendix F

Nutrient Influenced Impairments on Streams Having or Needing a TMDL

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Kansas-Lower Republican Basin				
Kansas River below Topeka	TMDL			
Kansas River at Lawrence	TMDL			
Lower Kansas River below DeSoto	TMDL			
Upper Wakarusa River	TMDL			
Mill Creek (Jo.Co)	TMDL			
Crooked Creek	TMDL			
Kansas River at Lecompton	Listed			
Kansas River at Willard	Listed			
Mission Creek	Listed			
Soldier Creek	Listed			
West Brnch Mill Creek (Wb Co.)	Listed			
Vermillion Creek	Listed			
Stranger Creek	Listed			
Black Vermillion River	Listed			
Big Blue River	Listed			
Little Blue River	Listed			
Republican River	Listed			
Wildcat Creek	TMDL			
Salt Creek	TMDL			
Washington Creek	TMDL			
Shunganunga Creek		Listed		
Coal Creek		Listed		
Cedar Creek (Jo.Co)				Listed

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Lower Arkansas Basin				
Arkansas River at Wichita	TMDL			
Arkansas River at Ark City	TMDL		Listed	
Little Arkansas River	TMDL			
Cowskin Creek	TMDL		Listed	
Arkansas River at Hutch/Yoder	Listed		TMDL	
North Fork Ninnescah			TMDL	
South Fork Ninnescah			TMDL	
Little Cow/Cow Creeks	TMDL			Listed
Turkey Creek	TMDL			
Bluff Creek	TMDL			
Silver Creek	TMDL			
Sand Creek		Listed		Listed
Emma Creek		Listed		
Black Kettle Creek		Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Upper Arkansas Basin				
Arkansas River at Great Bend	TMDL			
Arkansas River below Garden City			TMDL	
Mulberry Creek		Listed		
Pawnee River		Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Cimarron Basin				
Cimarron River			TMDL	

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Marais des Cygnes Basin				
110 Mile Creek		TMDL		
Upper Marais des Cygnes/142 Mile Crk		TMDL		
Pottawatomie Creek	Listed	TMDL		
Dragoon Creek		TMDL		
Ottawa Creek		TMDL		
Middle Creek		TMDL		
Marmaton River	TMDL	TMDL		
Appanoose Creek		Listed		
Big Sugar Creek		Listed		
Salt Creek		Listed		
Little Osage River		Listed		
WF Dogwood Creek		Listed		
Marais des Cygnes at Ottawa	Listed	Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Missouri Basin				
Blue River	TMDL	Listed		
Wolf River	Listed			
SF Big Nemaha River	Listed			
Indian Creek				Listed

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Verdigris Basin				
Lower Verdigris River at Coffeyville	TMDL			
Upper Verdigris River at Virgil	Listed	Listed		
West Creek		TMDL		
Walnut Creek		TMDL		
Chetopa Creek		TMDL		
Upper Fall River		TMDL		
Upper Elk River		TMDL		
Pumpkin Creek		TMDL		
Onion Creek		TMDL		
Big Hill Creek		TMDL		
Middle Caney River		Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Neosho Basin				
Dows Creek		TMDL		
Eagle Creek		TMDL		
French Creek		TMDL		
Turkey Creek (Coffey Co)		TMDL		
Canville Creek		TMDL		
Labette Creek		TMDL		
Cherry Creek		TMDL		
Shawnee Creek		TMDL		
Bachelor Creek		TMDL		
Neosho River at Chanute			TMDL	
Fox Creek/Palmer Creek	TMDL			
South Fork Cottonwood River	TMDL			
Upper Neosho River at Emporia		Listed		
Munkers Creek		Listed		
Big Creek		Listed		
Long Creek		Listed		
Turkey Creek (Cherokee Co)		Listed		
Cow Creek		Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Walnut Basin				
Walnut River (Butler Co.)	TMDL			
Walnut River (Cowley Co.)	TMDL			

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Smoky Hill – Saline Basin				
Smoky Hill River (Trego Co.)		TMDL		
Holland Creek		TMDL		
Spillman Creek		TMDL		
Smoky Hill River at Salina	TMDL			
Smoky Hill River at Ellsworth	Listed			
Big Creek		Listed		
Gypsum Creek		Listed		
Solomon Basin				
South Fork Solomon River	TMDL			
Limestone Creek		TMDL		
Twin Creek		TMDL		
Browns Creek		TMDL		
Oak Creek		Listed		
Deer Creek		Listed		

Stream/Watershed	Biology	Dissolved Oxygen	pH	NO3
Upper Republican Basin				
Lower Prairie Dog Creek		TMDL		
South Fork Republican River			TMDL	
Arikaree River			Listed	
Beaver Creek		Listed		

Appendix G

Water Supply Lakes

Public Water Supply	Source	County	Population Served
Garnett	City Lake & Crystal Lake	AN	3,374
Bourbon Co. RWD #4	Xenia Lake	BB	465
El Dorado	El Dorado Res.	BU	12,669
Augusta	El Dorado Res. & City Lake	BU	8,493
Winfield	Timber Creek Lake	CL	12,214
Sedan	2 City Lakes	CQ	1,294
PWWSD # 11	Bone Creek Res.	CR	14,784
Douglas Co. RWD #3	Clinton Res.	DG	3,834
Lawrence	Clinton Res.	DG	81,604
Herington	City Lake	DK	2,496
Howard	Polk Daniels Lake	EK	779
Moline	Watershed Lake & 2 city Lakes	EK	439
Ellsworth Co. RWD #1	Kanopolis	EW	2,626
Richmond	City Lake	FR	514
Milford	Milford Res.	GE	482
Severy	City Lake	GW	364
Madison	City Lake	GW	845
Eureka	City Lake & Res. W-7	GW	2,888
PWWSD #18	Banner Creek Res.	JA	5,802
Holton	Prairie Lake & #18	JA	3,302
Perry COE-Longview	Perry Res.	JF	25
Gardner	City Lake	JO	12,000
Olathe	City Lake	JO	109,571
Spring Hill	Hillsdale	JO	4,000
PWWSD #4	Big Hill	LB	10,283
Parsons	City Lake	LB	11,289
Mound City	City Lake	LN	860
Pleasanton	City Lake	LN	1,384
Linn Valley Lakes	City Lake	LN	577
Blue Mound	City Lake	LN	276
Mitchell Co. RWD #2	Glen Elder Res.	MC	1,291
Caney	Twin Caney Res.	MG	2,032
Louisburg	City Lake	MI	2,764
Miami Co. RWD #2	Hillsdale	MI	8,631
Paola	Lake Miola	MI	5,048
Hillsboro	Marion Res.	MN	2,833
Marion	Marion Res.	MN	2,063
Council Grove	City Lake	MR	2,315
Sabetha	City Lake	NM	3,100
Thayer	City Lake	NO	532
Norton	Norton Res.	NT	2,956
PWWSD # 12	Melvern Res.	OS	7,314
Osage City	Melvern Res. & City Lake	OS	3,027
Osage Co. RWD #3	Pomona Res.	OS	900
Carbondale	Strowbridge Res.	OS	1,468
Russell	Fossil Lake	RS	4,732
Wichita	Cheney Res.	SG	362,876
Wellington	Lake Wellington	SU	8,421

Public Water Supply	Source	County	Total
Harveyville	City Lake	WB	254
Eskridge	Lake Wabaunesee	WB	570
Alma	Old & New City Lake	WB	762
Buffalo	Quarry Pits	WL	279
Yates Center	City Lake	WO	1,599
Toronto	Toronto Res.	WO	301
		Total	**732,227**